Jaycar Electronics

SHORT CIRCUITS

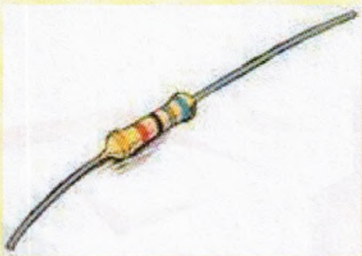
Editorial Director: Gary Johnston

VOLUME 2: FIRST EDITION

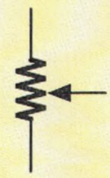
How to recognise components...

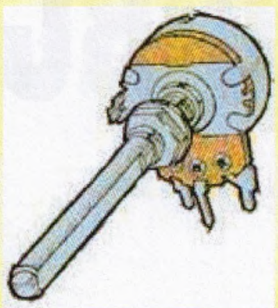
Resistors — fixed and variable

RESISTOR



POTENTIOMETER

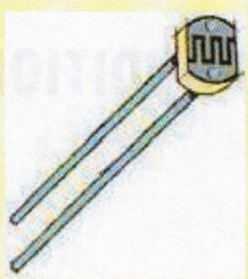




TRIMPOT

OR

LIGHT DEPENDENT RESISTOR (LDR)



RESISTORS are used to regulate the amount of current flowing in a circuit — the higher the resistor's value or resistance, the less current that flows and vice-versa. Resistor values are measured in ohms (Ω) and are identified by the colour bands on their bodies (see page 25). They may be connected into a circuit either way around (ie, they are not polarised).

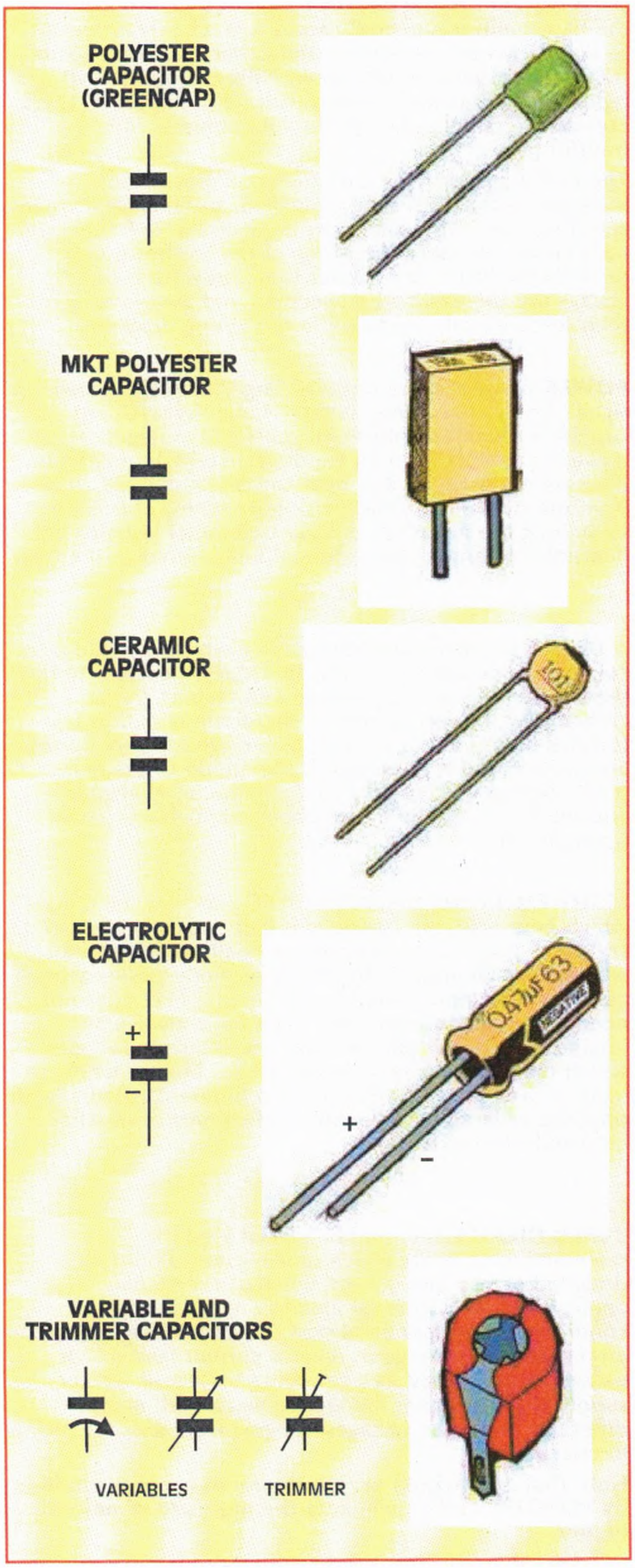
Resistors are made in different sizes, capable of dissipating or 'getting rid of' different amounts of energy (as heat). They are also made using different materials as the actual resistive element. Small low power resistors usually have an element made from either carbon or a thin film of metal. Larger resistors made to dissipate more power generally have an element wound from a wire such as *nichrome* (nickel-chromium alloy).

A **POTENTIOMETER** (or 'pot') is basically a variable resistor. It has three terminals and is fitted with a rotary control shaft or spindle. Rotating this shaft varies the position of a wiping metal contact on a circular carbon resistance track inside the pot body, and this in turn determines the resistance between the wiper (centre terminal) and the two outer terminals. Potentiometers are commonly used as volume controls.

A **TRIMPOT** is a special type of potentiometer which, while variable, is intended to be adjusted once or only occasionally. For this reason a control shaft is not included, but instead a slot or cross cutout is provided in the centre of the wiper rotor so it can be adjusted using a small screwdriver. Some trimpots are made with their total resistive element and wiper rotor exposed, while others are enclosed in a small plastic case.

A **LIGHT DEPENDENT RESISTOR** (or LDR) is a special type of resistor that varies its resistance value according to the amount of light falling on it. When it is in the dark, an LDR will typically have a very high resistance (eg, millions of ohms), but this will fall to just a few hundred ohms when the LDR is exposed to strong light. They are not polarised.

Capacitors – fixed and variable



CAPACITORS block DC (direct current) while allowing varying or AC (alternating current) signals to pass. They are commonly used for coupling signals from one part of a circuit to another, and in timing circuits.

POLYESTER capacitors use polyester plastic film as their insulating dielectric. Some polyester capacitors are called *greencaps* since they are coated on the outside with green (or brown!) plastic to keep out dust and moisture. Their values are specified in microfarads (µF), nanofarads (nF) or picofarads (pF), and range from 1nF up to about 10µF. (See page 39 for capacitor codes.) They are not polarised. Most of the projects in this book use greencaps for their medium value fixed capacitors.

MKT capacitors are another type of polyester capacitor, but they are in a rectangular 'block' shape and are usually yellow in colour. One of the major advantages of MKT capacitors is a more standardised lead spacing, making them more useful for PC boards. In most circuits, MKT capacitors can always be substituted for greencaps if you wish.

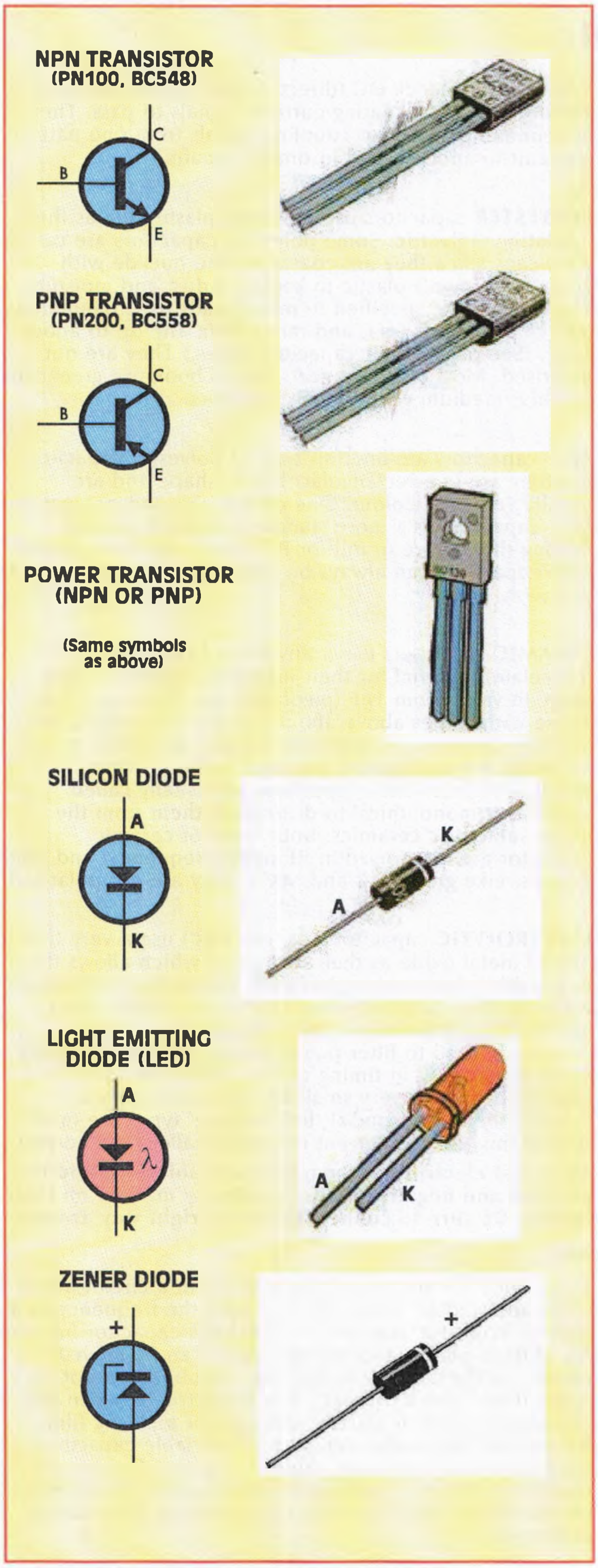
CERAMIC capacitors use a tiny disc of ceramic (porcelain) material for their insulating dielectric, and range in value from 1pF (picofarad) up to about 2.2µF. Those with values above about 1nF are often made with multiple layers of metal electrodes and dielectric, to allow the higher capacitance value to be provided in a smaller volume. These capacitors are usually called 'multilayer monolithics' to distinguish them from the lower value disc ceramics. Both types of ceramic capacitor are often used in RF (radio frequency) and filter circuits. Like greencaps and MKTs, they are not polarised.

ELECTROLYTIC capacitors (or 'electros') use a very thin film of metal oxide as their dielectric, which allows them to provide a large amount of capacitance in a very small volume. They range in value from about 100nF up to hundreds of thousands of microfarads (µF). They are commonly used to filter power supply rails, for coupling audio signals and in timing circuits. All electrolytic capacitors allow a very small DC 'leakage' current through them, but special 'low leakage' types are made so that this leakage current is much smaller than normal.

Note that electrolytic capacitors are polarised and the positive and negative leads are clearly marked on their bodies. Be sure to connect them the right way around.

Sometimes the amount of capacitance in a circuit needs to be adjusted or 'trimmed' — setting the frequency of a tuned circuit, for example. A **VARIABLE** capacitor has one set of fixed plates, and one set which can be moved relative to them either by turning a knob (like a pot) or a screwdriver (like a trimpot). The dielectric between the two sets of plates is usually either air or a plastic film. Because of their construction, most variable capacitors have quite low maximum values — up to a few tens of picofarads (pF) for trimmer capacitors and a few hundred picofarads for larger variable capacitors used for tuning radios, etc.

Semiconductors: Transistors and Diodes



TRANSISTORS are semiconductor devices that can either be used as electronic switches or to amplify signals. They have three leads, called the *collector*, *base* and *emitter*. A small current flowing between base and emitter (through the base-emitter junction) causes a much larger current to flow between the emitter and collector. Two types of transistor are used in this book: **NPN** types and **PNP** types. Transistors are labelled with 'Q' numbers (Q1, Q2, etc) on the circuits, so they're not confused with transformers.

The PNP transistors used in this book mostly look identical to the NPN types specified, so be careful when selecting them. You can easily recognise a PNP transistor on a circuit, because the arrow of the emitter points towards the base 'bar', rather than away. Be sure to always use the exact type specified and always connect their leads exactly as shown in the wiring diagrams.

POWER transistors are (usually) larger than the 'small signal' types above and, as their name suggests, are capable of handling higher currents and voltages. Most power transistors have an exposed metal tab, or part of the case exposed, so that heat can be conducted away from the transistor's 'internals' more easily. This is done by bolting the metal tab or case to a metal radiator or heatsink, to form a close thermal bond between the two.

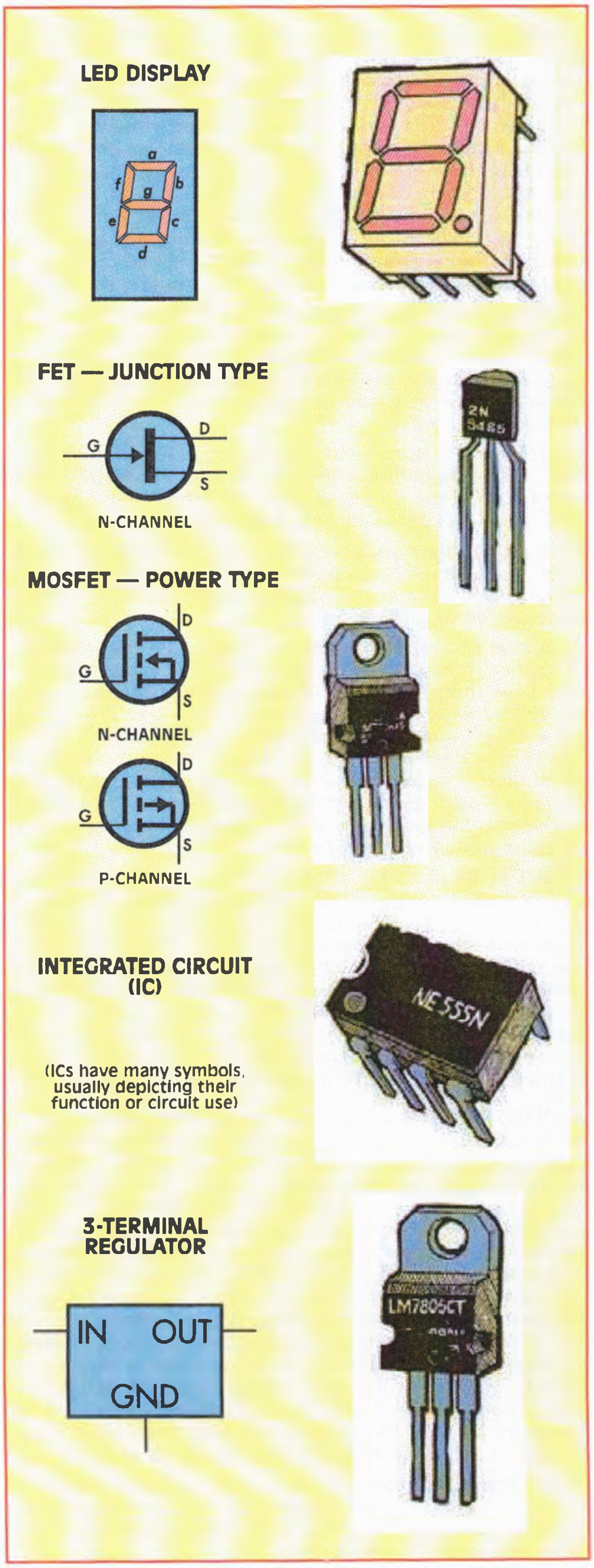
A **DIODE** is a semiconductor device which can can pass current in one direction only. In order for current to flow, the anode (A) must be positive with respect to the cathode (K). In this condition, the diode is said to be forward biased and a voltage drop of about 0.6V appears across its A and K terminals. If the anode is less than 0.6V positive with respect to the cathode, negligible current flows and the diode effectively behaves as an open circuit.

LIGHT-EMITTING DIODES or 'LEDs' are special diodes which have a plastic translucent body (usually clear, red, yellow or green in colour), and a small semiconductor element which emits light when the diode passes a small current. Unlike an incandescent lamp, a LED does not need to get hot to emit light. LEDs must always be forward biased to operate. They are available in types which emit red, orange, yellow, green, blue or white light, as well as types emitting two different colours (with opposite polarity or different connections) or invisible infra-red (IR) radiation.

ZENER DIODES are another special kind of semiconductor diode which unlike other diodes, is designed to conduct current when a *reverse bias* is applied across its internal junction. Under these conditions it displays an almost constant voltage drop, for a relatively large range in reverse current levels. This voltage is often used as a reference voltage in power supply circuits. Zener diodes are made with many different reference voltages, ranging from about 3.3V up to over 75V.

Note that the striped or 'band' end of a zener diode is its POSITIVE end — which is the opposite of normal diodes.

Other Semiconductor Devices



LED DISPLAYS consist of a number of LEDs together in a single package. The most common type has seven elongated LEDs arranged in an '8' pattern. By choosing which combinations of the LEDs are lit, any number digit from '0' through '9' can be displayed. Most of these '7-segment' LED displays also contain another small round LED which can be used to display a decimal point.

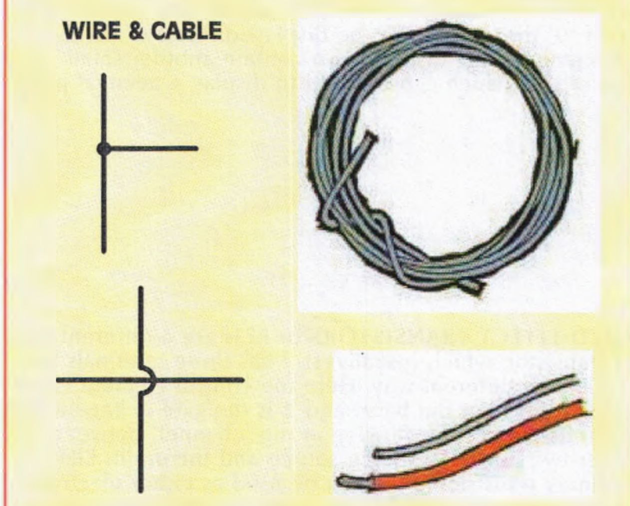
FIELD-EFFECT TRANSISTORS or FETs are a different type of transistor, which (usually) still has three terminals but works in a different way. Here the control element is the *gate* rather than the base, and it is the gate *voltage* which controls the current flowing in the 'channel' between the other two terminals — the *source* and the *drain*. Like ordinary transistors FETs can be used as either electronic switches or amplifiers. They come in both P-channel and N-channel forms (similar to PNP and NPN transistors), and are available in both small signal and power types.

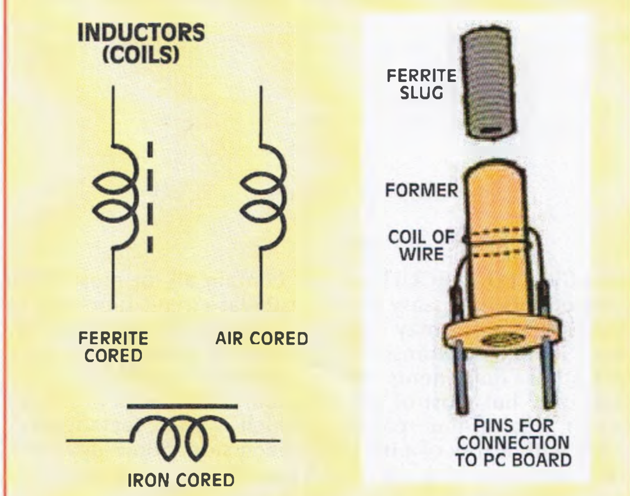
INTEGRATED CIRCUITS or ICs contain all, or most of the components necessary for a particular circuit function, in one package. ICs may contain as few as 10 transistors or many millions of transistors, plus many resistors, diodes and other components. There are many shapes, styles and sizes, but most of the ICs used in this book are in a DIL or 'dual-in-line' package, which is a flat rectangular block with a row of pins down each side. Some devices have two rows of 4 pins (ie, 8 pins in all), while others have two rows of 7, 8 or even 9 pins.

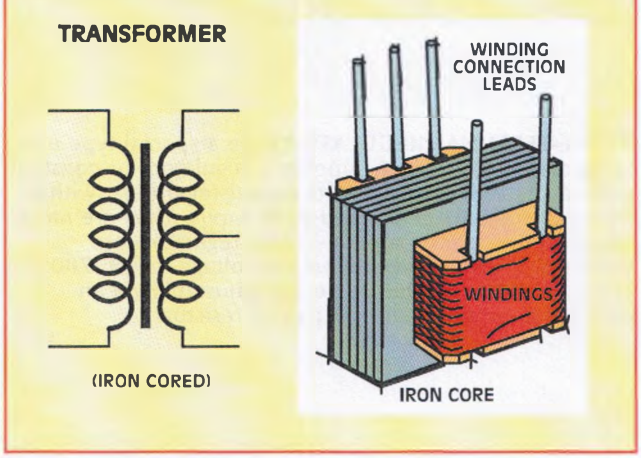
Pin 1 of the IC is usually indicated by a small 'dimple' or depression on the top of the package. There may also be a small semicircular notch moulded into that end of the package. Looking down on the IC, the pins are always numbered anticlockwise from pin 1.

THREE-TERMINAL REGULATORS are a special type of integrated circuit which supplies a regulated, or constant and accurate, voltage from its output regardless (within limits) of the voltage applied to its input. They are most often used in power supplies. Most regulators are designed to give a specific output voltage (eg, a '7805' regulator gives 5V), but some are adjustable via an external potentiometer or a pair of resistors.

Wire, cable, Inductors and Transformers







A **WIRE** is simply a length of metal conductor, usually (but not always) made from copper. Copper is almost always used for wire because of its excellent electrical conductivity (the ability to conduct a current). When there is a risk of a wire touching another wire and causing a short circuit (such as in an inductor or coil), the copper is coated or covered in an insulating material. A very thin coating of enamel (like a varnish or paint) may be used for this insulation, or else it is enclosed in a sleeve of coloured PVC (polyvinyl chloride) plastic. Unless the wire gets very hot or the design voltage is exceeded, this sleeve will continue to insulate the wire.

Plain copper wire is not generally used because it will oxidise or tarnish in the presence of air. A thin metal alloy coating is therefore applied to the copper, usually an alloy of tin and lead which makes it easy to solder but doesn't oxidise as easily as copper itself. This produces *tinned copper wire*.

Single or multi-strand wire which is covered in coloured PVC plastic insulation is used quite a lot in electronics, to connect or 'hook up' PC boards and other components. As a result it is generally called *hookup wire*.

On a circuit diagram, a solid dot indicates that the wires or PC board tracks are connected or joined, while a 'loop-over' indicates that they are not joined and must be insulated from each other.

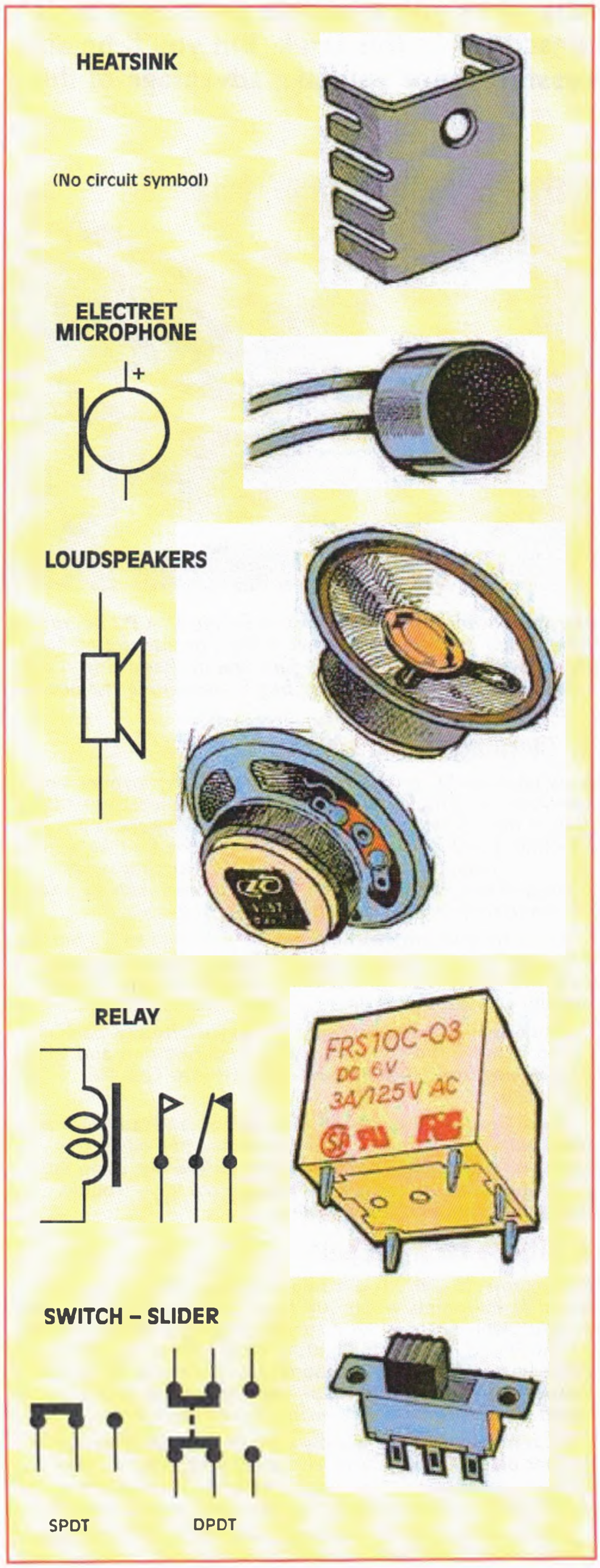
A number of insulated wires enclosed in an outer sleeve of insulating material are called a **CABLE**. Some cables may have three multi-strand wires, with insulation capable of withstanding over 240V AC — like the power cable used on most domestic electrical appliances. Other cables may have a single wire running down the centre of a cylinder of insulation, with a second conductor made of many woven strands of fine wire around it, and then a further insulating sleeve on the outside. This is generally called *screened* or *coaxial cable*.

INDUCTORS or 'coils' are basically a length of wire (either tinned copper or enamel-coated wire), wound into a cylindrical spiral (or layers of such spirals) in order to increase their inductance (the ability to store energy in a magnetic field). Many coils are wound on a *former* of insulating material, which may also have connection pins to act as the coil's terminals. The former may also be internally threaded to accept a small core or 'slug' of ferrite material, which can be adjusted in position relative to the coil itself to vary the inductance.

A **TRANSFORMER** consists of a number of coils or *windings* of wire wound on a common former, which is also inside a core of iron alloy, ferrite or other magnetic material. When an alternating current is passed through one of the windings (the *primary*), it produces an alternating magnetic field in the core and this in turn induces AC voltages in the other (*secondary*) windings. The voltages produced in the other windings depend on the number of turns in those windings, compared with the turns in the primary winding. If a secondary winding has fewer turns than the primary, it will produce a lower voltage; if it has more turns, it will produce a higher voltage. In other words, the voltage ratio is directly proportional to the turns ratio. Transformers can therefore be used to change the voltage level of AC power — either for stepping the voltage up or down.

Transformers are made in many sizes, and with many different combinations of windings. They are frequently used in power supplies. The larger the transformer, the more AC power it can handle.

Microphones, Speakers and Hardware



Many electronic components generate a certain amount of heat when they are operating. While most can cope with this heat, some are not capable of removing all the heat they generate and may eventually be damaged or destroyed if they aren't helped to remove it. A **HEATSINK** is a device which makes intimate thermal contact with the device (most likely a transistor or other semiconductor) and draws the heat from it, keeping it cooler and radiating the heat to the surrounding air.

A **MICROPHONE** converts audible sound waves into electrical signals which can then be amplified (eg, in a publica address system), fed to a radio transmitter or processed in some other way. In an **ELECTRET** microphone the sound waves vibrate a circular *diaphragm* made from very thin plastic material which has a permanent electric charge in it. Metal films coated on each side form a capacitor, which produces a very small AC voltage when the diaphragm vibrates. All electret microphones also contain a FET (field effect transistor), which amplifies the very small AC signals. To power the FET amplifier the microphone must be supplied with a small DC voltage. All electret microphones are therefore polarised.

A **LOUDSPEAKER** (or 'speaker') converts electrical signals into sound waves that we can hear. It has two terminals which go to a 'voice coil' (essentially a coil of wire) attached to a circular cone made of either cardboard or thin plastic. When electrical signals are applied to the voice coil, it creates a varying magnetic field which interacts with the adjacent magnetic field from a permanent magnet at the back of the speaker.As a result the cone vibrates in sympathy with the applied signal to produce sound waves. Although the speaker terminals may be marked with '+' and '–' signs, a speaker may be regarded as a non-polarised device when used in the projects described in this book.

Many electronic components are not capable of switching higher voltages or currents, so a **RELAY** is used. This has a coil which forms an electromagnet, attracting a steel 'armature' which itself pushes on one or more sets of switching contacts. When a current is passed through the coil to energise it, the moving contact(s) disconnect from one fixed contact and connect to another. Then when the coil is de-energised, the moving contact(s) return to their original position(s). In most cases the relay coil needs a diode across it to prevent damage to sensitive semiconductor devices controlling the coil current.

A **SWITCH** is a device with one or more sets of switching contacts, which are used to control the flow of current in a circuit. The switch allows the contacts to be controlled by a physical actuator of some kind — such as a press-button, toggle lever, rotary spindle and knob, or a slider bar. As the name suggests, this last type of switch has an actuator bar which slides back and forth between the various contact positions. In a single-pole, double throw or 'SPDT' slider switch, a moving contact links the centre contact to either of the two end contacts. In contrast a double-pole double throw or DPDT slider switch has two of these sets of contacts, with their moving contacts operating in tandem when the slider is actuated. ★

How to Build Kit Projects

Building electronic projects isn't hard, especially when you assemble them from a kit like those we make available for the projects described in this book. But you'll be able to build them a lot more confidently and successfully once you take advantage of the practical techniques we explain here...

IN THE VAST majority of modern electronic projects, most if not all of the small parts or 'components' are mounted on a printed circuit or PC board which has etched copper tracks on at least one surface, to provide most of the actual wiring. This makes construction a lot easier than in the old days of electronics. All of the projects described in this book are built on a PC board, for this reason.

Although today's components are also a lot smaller than in the old days, they're usually fairly rugged and easy to work with. However at the same time it is still possible to damage them if you don't handle them the right way. And of course a damaged component can easily result in a project that doesn't work as it should. So knowing the right practical techniques and using them is generally the best way to ensure that your projects will work properly as soon as you've finished building them.

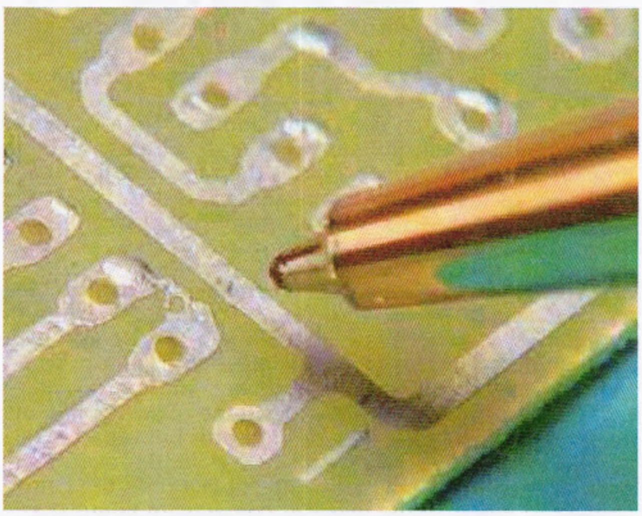
In this chapter we're going to run through most of the practical steps that you'll need to know about, in roughly the order they occur when you're building any electronic project. The only technique we won't discuss is soldering, which is covered in its own chapter.

1. Got everything?

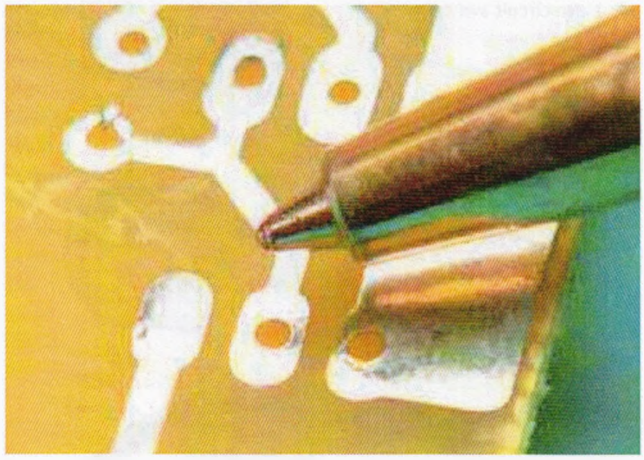
Before you start to build anything it's a very good idea to make sure you have all the parts. This is still necessary when you're building an electronics project from a kit — because mistakes can happen, and sometimes parts can be omitted from a single kit or even a batch of kits.

So clear your bench or worktable, open up the kit and lay out all the parts so you can check them off against the project's parts list. Now's the time to find out if you're missing anything, so you can get it from your supplier.

If everything is present and correct, put them all in a plastic dish or tray so none of them rolls off the bench and gets damaged or lost.



One kind of manufacturing fault which can occur when a PC board is being made is a copper 'bridge' which provides a short circuit between IC pads. If you find one, like the example shown here, cut it away using a hobby knife...



Here's another kind of fault you may find in a PC board: a hole which has either not been drilled, or was drilled but then covered in solder. If you find one of these, drill it out with a 0.8mm drill before you begin assembling the board.

2. Checking the PC board

Now take the PC board itself, and inspect the copper side carefully for manufacturing defects — using a magnifying glass if necessary. What you're mainly looking for is things like fine 'hairline' cracks in any of the etched tracks, or tiny slivers of solder that may have been left from the solder plating of the tracks, bridging a gap between pads or tracks and therefore forming an unwanted short circuit.

If you do find any hairline cracks, you need to re-join the tracks by either soldering a short length of tinned copper wire over the crack, or in some cases just running a small amount of solder over the crack with your soldering iron.

Similarly if you find any solder bridges between pads or tracks, remove these by using your soldering iron and some desoldering braid (Jaycar stores stock this as Cat. No. NS-3020).

If you discover that any of the component lead holes are filled with solder (this can sometimes happen when the board is solder plated), it should be sucked out using the soldering iron and braid. Otherwise you'll have trouble fitting the component leads later.

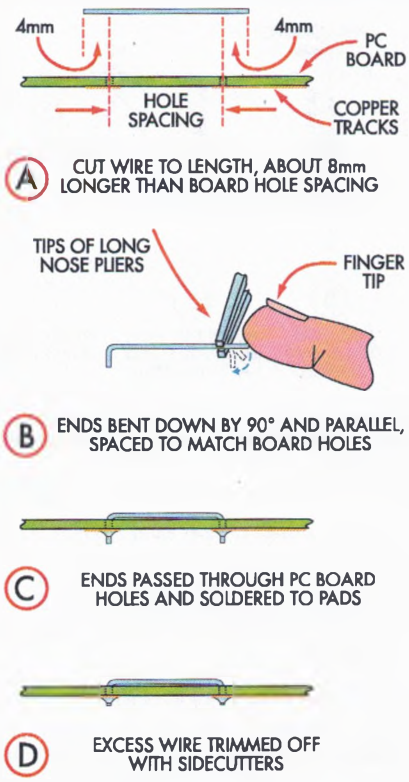
3. Fit any terminal pins

Many projects and kits use small terminal pins on the PC board at the points where 'off board' connections are made: in other words, connections to anything that isn't mounted on the board itself, like a battery or headphones. Fitting these terminal pins to the board makes it easier to solder connecting wires to the board, especially from above and when the board may have been mounted in a box.

PC terminal pins are usually a piece of 1mm diameter copper or brass wire about 10-12mm long, with a small flange formed about 5mm from one end. They're often either gold or silver plated, to make them easier to solder.

The pins are fitted by pushing their 'short' ends through the 1mm holes provided in the PC board, from the top and

MAKING AND FITTING WIRE LINKS



Some PC boards use wire links to make connections that need to cross over. Here's how the links are made and fitted.

until the flange is resting against the top of the board. Then the board is turned copper side up, and each pin soldered to the pad around its hole. The short stub of each pin left protruding from the solder joint is then clipped off using your sidecutters.

So if the project you're building uses any terminal pins, it's a good idea to fit them at an early stage.

4. Any wire links to fit?

Often the designer of a low-cost single layer PC board has to make use of a wire link or two on the board, to complete connections which really need to 'cross over' other connection tracks. If the project/kit you're building uses these links (and this applies to some of the projects in this book), they too are best fitted before you fit any of the electronic parts.

When they're short, the links can often be made from 'offcuts' from resistor or capacitor leads. Otherwise you can make them from 0.5mm tinned copper wire (preferably stretched slightly, so it's straight and stiffer). On the other hand if the links are quite long and/or there are a few of them running closely next to one another, it's a good idea to make them from short lengths of insulated single-core hookup wire.

To make the links, measure the distance between the two holes provided on the board for the link ends and then add about 8mm to find the total length you need. Cut off this length of wire, and if you're using insulated wire strip off about 4mm of insulation at each end. Then using your long nose pliers, carefully bend down each end 4mm in, at 90° and with both ends bent in the same direction.

The link can then be fitted to the board by passing these two short 'legs' through the board holes. Then they're bent over at about 45° to hold the link in place while you solder them to the pads around each hole. Any surplus wire protruding from the solder joint can then be clipped off with the sidecutters.

5. Preparing & fitting resistors

Most of the resistors fitted to project PC boards are mounted 'horizontally' — that is, with their body lying down against the top of the board. The resistor's **axial** leads (ie., emerging from each end, on the axis) are bent down so that they pass through the holes provided on the board, usually at a spacing of either 12.5mm (0.5") or 10mm (0.4").

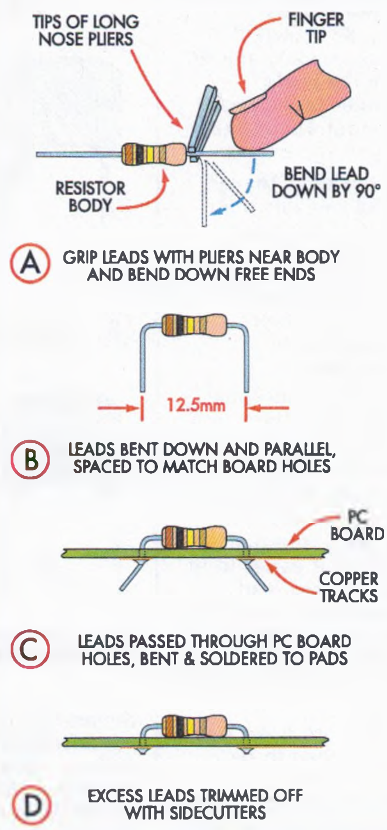
To mount the usual 0.25W or 0.5W carbon or metal film resistors in this way, take each one in turn and carefully bend each of its leads down through 90°, at a point about 3mm away from the resistor body. Do this by gripping the lead with the tips of the long nose pliers just inside the 3mm point, and then bending the free end with your finger down against the side of the pliers. Both resistor leads are bent in the same direction of course, because the bent portions will be passed through the holes in the PC board when the resistor is fitted to it.

Once the leads of all resistors have been bent in this way, check each one's colour code to make sure of its value and therefore where it should go on the board.

Resistors are not polarised components of course, so in most cases they can be fitted into the board either way around without making any difference electrically. However if you want your project to look professional, the idea is to fit all of the resistors so their colour coding bands can be read in the same direction. This makes it a lot easier for anyone (including you) trying to troubleshoot in your project if this ever becomes necessary later.

Fit each resistor by pushing the bent ends through the correct board holes as far as they'll go, so that the body of the resistor is now lying down against the top of the board. Now turn the board over, and while you hold the resistor's body against the board with one hand, gently push over the two protruding leads by about 45° to hold the resistor in

PREPARING RESISTOR LEADS FOR HORIZONTAL MOUNTING



Most resistors have axial leads as shown here, but are mounted on a PC board horizontally. Here's how a resistor is prepared and mounted on the board this way...

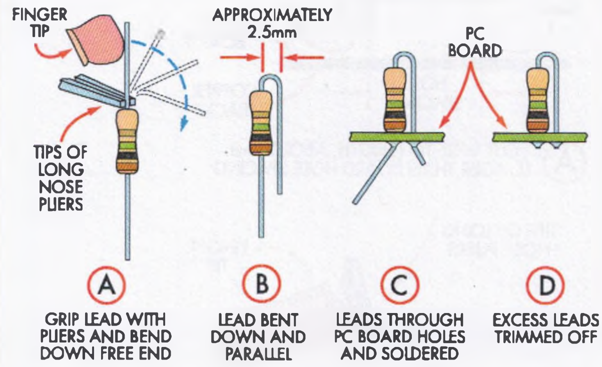
place. Then you can solder the leads to the copper pads, and finally trim off the surplus lead wire with your sidecutters.

Some projects assembled on a very compact PC board have some or all of the resistors mounted vertically on end, to save space. To mount resistors this way, you have to bend one of each resistor's leads carefully around with long nose pliers, so that its end becomes parallel with the unbent lead and only about 2.5mm away from it (see diagram at right). Make sure you don't strain the resistor itself when you're bending the lead.

With the lead bent around in this way, both leads can be pushed through the holes in the board and soldered — with the resistor body vertical and one end down against the board. Make sure that you mount each resistor value in its correct position. With some projects it's also important to orientate some resistors carefully so that their longer 'bent down' lead is connected to the earthy side of the circuit. This is usually shown in the wiring diagram for the project.

By the way, what we just called the 'earthy side' of the circuit is usually the side of the circuit which is connected to the *negative* supply line — i.e., the negative terminal of the battery or other power supply. It may not actually be connected directly to earth or ground, but it's the side of the circuit which is assumed to be 'cold', or at the lowest potential with respect to earth.

PREPARING RESISTOR LEADS FOR VERTICAL MOUNTING



Resistors are sometimes mounted vertically, to save space. Here's how a resistor is prepared and mounted on a PC board this way...

6. Non-polarised capacitors

Most smaller value capacitors are of the disc ceramic, multilayer monolithic ceramic or metallised polyester (greencap, MKT) film type, and are not polarised. So like a resistor, they can be fitted to the PC board either way around.

Nowadays almost all of these capacitors have **radial** leads — leads which emerge from the capacitor on the same side of its body, and roughly parallel with each other. So in many cases the capacitor is mounted on the PC board simply by passing the leads through the matching holes in the board, bending them over at about 45° and then soldering and trimming off the excess.

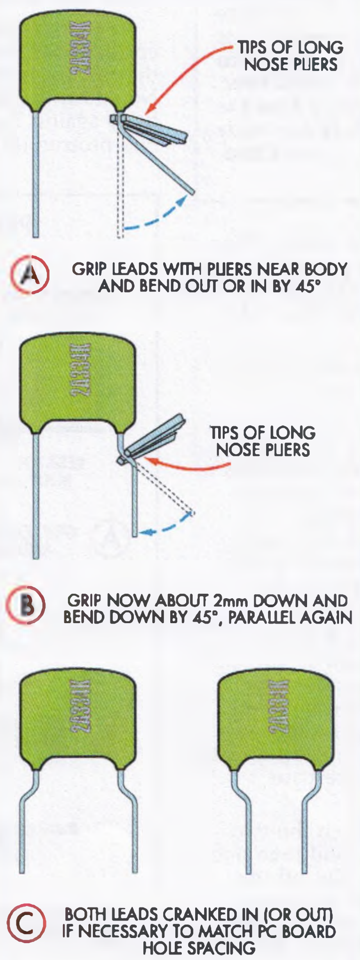
It's not always quite this easy, though, because the lead spacing can vary a bit even between capacitors of the same type and with the same value. So sometimes it's necessary to 'dress' the leads, cranking one or both of them either inwards or outwards so their spacing matches the board's hole spacing. (See diagram at right)

Do this very carefully with your long nose pliers, so you don't stress the component itself or loosen the attachment of the leads inside it.

In some kit projects (including many of those in this book) you'll find that the designer has provided extra 'alternative' holes in the board to make it easier to fit capacitors with widely differing lead spacing. This often means that you won't have to dress the leads at all, or very little — simply choose the combination of holes with the nearest spacing to that capacitor's lead spacing.

Mind you, when these extra holes **have** been provided, you often need to be very careful not to fit the capacitor between two hole pads that are meant to be alternatives for the same 'side' of the capacitor, and therefore connected together underneath by a copper track. If you fit the capacitor this way, it won't really be connected into the circuit. So make sure you use one hole and pad from those provided for each side of the capacitor.

'DRESSING' GREENCAP AND OTHER COMPONENT LEADS



Sometimes the radial leads of capacitors like 'greencaps' have to be cranked either outwards or inwards so they'll line up with the holes in the PC board. Here's how it's done...

7. Polarised capacitors

Larger value capacitors are usually of the aluminium electrolytic or solid tantalum type, of course. This means that they're **polarised**, and can only be fitted to the board one way around. This is called their **orientation**.

To help you in fitting them correctly, these capacitors always have at least one positive (+) or negative (–) marking on their body. Many electrolytics (or 'electros') have a 'stripe' of - signs along one side of the body, to make things even clearer. You'll also find that the wiring diagram for each project using polarised capacitors always shows at least a + sign near one mounting hole for each polarised capacitor, so you can be sure of its correct orientation.

Nowadays most polarised capacitors have radial leads, like their non-polarised cousins. So they're mounted in much the same way. They too can vary quite a bit in terms of lead spacing, so in some cases you may need to dress their leads inwards or outwards slightly to allow them to pass through the board holes easily. As before you need to do this very carefully with your long nose pliers, to avoid damaging the capacitor.

In the kit projects described in this book, you'll again find we've provided extra holes for some of the polarised capacitors, so you shouldn't need to dress their leads very often.

8. Fitting diodes

Most diodes are in an axial-lead package which is very similar in size and shape to a resistor. This means they're mounted in much the same way, by bending their leads down carefully at 90° so they will pass through the holes provided in the board — usually spaced either 12.5mm

(0.5") or 10mm (0.4") apart.

There's one big difference between a diode and a resistor, though: diodes are polarised, and must be orientated correctly if they're to work properly. Almost all diodes have a band of paint or ink around one end to indicate their cathode (K) end.

In the wiring diagrams for all of the projects in this book we've not only shown the diodes with their cathode bands clearly visible, but also provided 'A' and 'K' markings. So if you follow the wiring diagram carefully you shouldn't fit any of the diodes the wrong way around.

9. Fitting LEDs (light-emitting diodes)

The vast majority of LEDs are in packages with radial leads, with a standardised spacing of 2.5mm (0.1"). This means that they're usually very easy to fit to a PC board: you simply pass the two leads down through the holes in the board by the suggested distance, bend them over at 45° or so and then solder and trim.

In some cases both leads might have to be bent at 90° nearer the LED's body, if the LED is to project its light output in a horizontal direction rather than upwards. In these cases you'll probably find it easier to make this bend before you fit them to the board.

Don't forget that like ordinary diodes, LEDs are polarised and must be fitted to the board with the correct orientation. There are two ways to tell the orientation of most LEDs: If you check each one carefully you'll see that there's a 'flat' on one side of the plastic body. This indicates the cathode (K) lead. The two leads are also of unequal length, with the anode (A) lead about 2mm longer than the cathode lead.

In the wiring diagrams for most projects (including those for all the projects in this book) you'll find that the orientation of all LEDs is indicated with not only an 'A' and a 'K' but also a circular symbol with the flat clearly visible. So if you follow the diagram carefully, you shouldn't make any mistakes.

10. Fitting transistors

Most of the transistors used in project kits nowadays come in a small moulded 'TO-92' plastic package with the three leads emerging radially from the bottom, either close together in line or in a triangle formation. Often you'll find that they emerge from the package in line, but the centre lead has been 'cranked' to space it away from the other two and so form a triangular arrangement. (See diagram at right)

In the projects described in this book, most of the transistors we've used come with their leads inline, but spaced only about 1.25mm (0.05") apart. These could obviously have been fitted to the PC boards simply by passing the leads down through the board holes, if we had spaced the holes by the same small distance. However we haven't done this, because it would have meant that the copper pads around the holes would have to be both very small and with very tiny spaces between them — both of which would have made soldering much trickier, especially for newcomers. So we've spaced the board holes 2.5mm (0.1") apart, to make soldering easier.

As a result, though, you'll need to dress the outer leads of each transistor carefully outwards and away from the centre lead, so they become parallel again and spaced 2.5mm apart. Then the transistors can be mounted in each board position without any problems. This should be fairly clear from the diagram overleaf.

Of course transistors are again polarised, so they too have to be orientated correctly. In this case the transistor package shows the polarity quite clearly, because it has a 'D' cross-section with one side quite flat. In all of the wiring diagrams we show this flat side clearly to guide you in orientating each transistor correctly. So again, follow the wiring diagram closely and you shouldn't go wrong.

How far do you push the transistor's leads through the board holes, before you splay them and solder? Usually, as far as you can without straining the leads — which usually means up to the point where the outer leads are cranked.

11. Fitting ICs

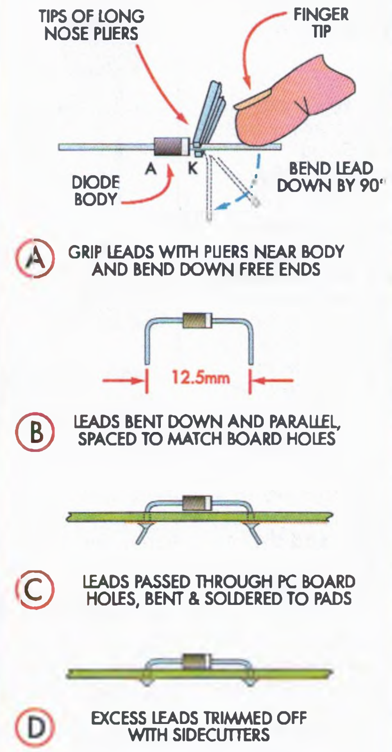
All of the ICs (integrated circuits) used in the projects in this book are in standard 'DIL' (dual-inline) packages. These are rectangular in shape, with rows of connection pins emerging along opposite longer sides. Many ICs are in an 8-pin DIL package, with two rows of four pins, while others are in 14-pin DIL (2 x 7 pins), 16-pin DIL (2 x 8 pins) or 18-pin DIL (2 x 9 pins) packages. The pins in each row are spaced 2.5mm (0.1") apart.

All of these devices have the pins already bent downwards with the two rows about 7.6mm (0.3") apart. This is the standard spacing for DIL packages, and the holes and pads on all PC boards designed to take them have the same spacing. So the idea is that the ICs are mounted by passing all of the pins through the board holes, and then soldering them underneath.

The only complication is that in many cases the IC pins are not bent down by 90°, but a bit less — so the two rows are spaced a bit wider than 7.6mm apart, and won't easily pass down through the board holes. They have to be bent inwards until their spacing is reduced to 7.6mm.

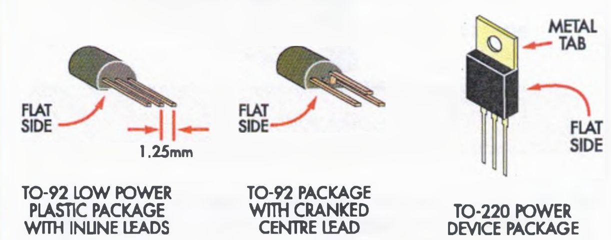
There are special 'IC insertion' tools available to do this, but these are a bit expensive. The alternative is to gently and carefully bend the two rows of pins inwards by hand,

PREPARING DIODE LEADS FOR HORIZONTAL MOUNTING



Power and signal diodes are fitted in much the same way as resistors — except that they're polarised, so they must be orientated correctly. The band at one end indicates the cathode (K).

COMMON TRANSISTOR PACKAGES



Here are the two most common packages used for discrete transistors, the TO-92 and TO-220. As you can see the TO-92 type can come with either all three leads in line, or with the centre lead cranked upward.

holding the body of the IC at the ends and rolling it with each row of pins against the benchtop (or another flat surface) so they're pushed evenly inwards a small amount. This is shown in the diagram below. Once you get the hang of this it isn't hard to do — just hold the IC carefully to avoid dropping it.

The only other thing to watch is that before you do this pin bending with CMOS devices like the 4093, 4017, 4024, 4066, 4511 or 4553, it's a good idea to discharge any static electric charge on yourself by touching some earthed metalwork (like a cold-water tap). Otherwise you might damage the IC.

Of course ICs are again polarised components, and must therefore be orientated the correct way around in order to work. The polarity of all ICs in DIL packages is indicated by a small semicircular notch at the centre of one end of the body, and often by a small 'dimple' depression on the top very close to the IC's pin 1. The wiring diagram for all of the projects in this book shows both the notch and dimple for each IC on the board, to guide you in fitting it correctly. So again, follow the wiring diagram.

12. Power transistors & regulators

Many power transistors and three-terminal regulators are in a rectangular package with a small metal 'heatsink' tab on one flat surface ('the back') and emerging at one end, and the three connection pins emerging inline at the other end, spaced 2.5mm (0.1") apart. This is known as the 'TO-220' package.

These devices are only used in one or two projects in this book, and where they are used they're fitted quite simply by passing the three pins down through the PC board holes and soldered. Like other transistors and ICs these devices are polarised though, and have to be orientated correctly. The wiring diagram always shows how to orientate them, with the metal heatsink tab on the correct side. So as before if you follow the wiring diagram carefully you shouldn't have any problems.

13. Any coils to wind?

There's only one project in this book that uses small air-wound coils (project 22), and we hope to be able to supply these coils pre-wound in all of the kits for this project. However just in case this isn't possible in the occasional batch, we tell you how to wind these coils yourself in that chapter. It's really quite easy, as you'll see.

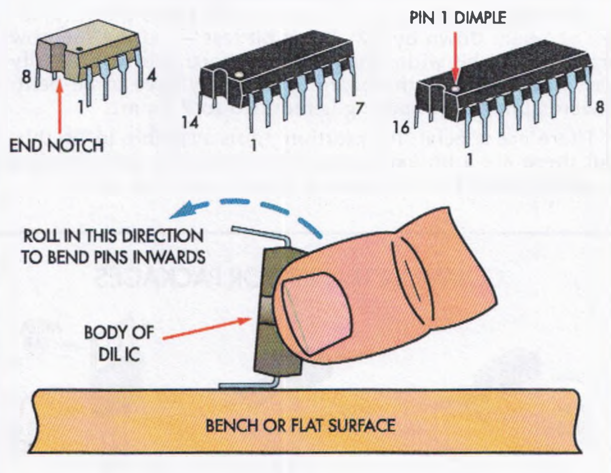
14. Checking before powering up

The last step of all, before you connect the battery to any project you've built, is to check everything very carefully all over again just in case you've made a wiring mistake. It's better to find and fix any mistakes now, because they might easily result in a component being damaged when the battery is connected.

Check that you've placed all resistors and capacitors in their correct position on the board, and that all of the polarised parts (electrolytic capacitors, diodes, LEDs, transistors and ICs) are orientated correctly as shown on the wiring diagram. Also examine all of your solder joints under the board, to make sure there aren't any dry joints or otherwise faulty connections — including slivers of solder forming short circuits between pads. In our experience, poor soldering accounts for over 70% of problems in electronics kit construction. Don't say you weren't told!

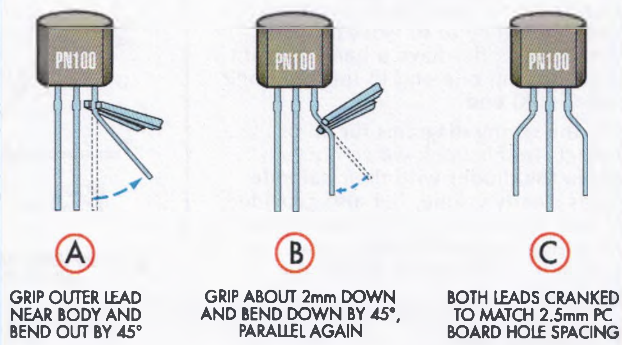
Everything look OK? Good, because this means that as soon as you hook the project up to a battery it should spring to life and do exactly what it's supposed to do. ★

DIL IC PACKAGES & PREPARING THEM FOR INSERTION



All of the ICs used in the projects we describe in this book come in DIL packages like those illustrated at the top here, with either 8, 14, 16 or 18 pins. The rows of pins of many DIL devices are often splayed out so they're slightly wider than the correct spacing of 7.6mm, and need to be bent inwards slightly before they'll fit into the board holes. An easy way of doing this is shown here.

'DRESSING' TO-92 TRANSISTOR LEADS



With transistors in the TO-92 package, you often need to crank their two outer leads to increase their spacing to match that of the holes in the PC board...

It just won't go? Some handy advice

What happens if your project doesn't work, even after you have 'tried everything'?

It is not at all unusual to find that your circuit will not 'go' at first. You proceed through your troubleshooting (checking solder joints, component orientation, the right resistors in the right place, flat battery etc.,) and STILL it doesn't work! It may give you little comfort, but this is pretty common. Before you decide that the 'circuit god' is picking on you, though, consider this:

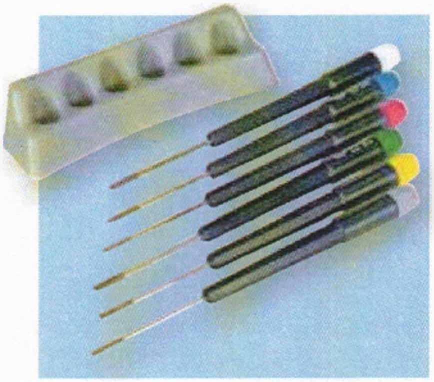
If all the parts are functional, they are all in the right location and orientated correctly, and reliable power is available, THE LAWS OF PHYSICS DEMAND that the circuit will work. There is no alternative!

Don't forget that thought. Cling to it. No one is picking on you, so go back to the beginning. Assume nothing, and methodically check through everything again. You WILL find the fault, if you try hard enough.

One of the greatest lessons you will learn from electronics construction is the discipline of logical, rational thought and analysis. It will pay you back in everything you do for the rest of your life.

The Tools You're Going To Need

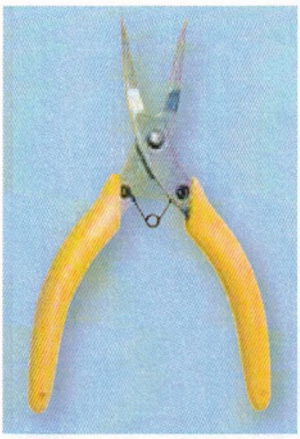
If the projects in this book are your first experience with "hands on" electronics experimenting and construction, here's a quick guide to the basic hand tools you'll need for this kind of work. There are quite a few other tools which will make things even easier (including a multimeter, which is discussed separately) but these are the ones you'll use the most often.



A set of small screwdrivers is essential for all kinds of jobs: loosening and tightening terminal blocks, opening and reassembling instrument boxes, fitting printed circuit boards and other parts inside boxes, fitting cables with plugs and sockets and so on. The Jaycar TD-2017 Precision Screwdriver Set gives you four flat-bladed drivers plus two cross-blade drivers for Phillips-head screws, all mounted in a handy wall holder.

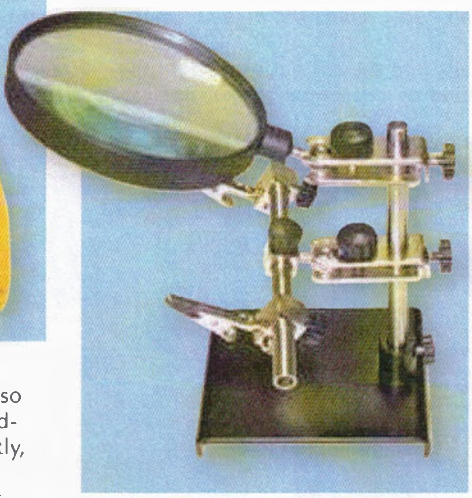
A low-power, electronics type soldering iron is a must. In the Jaycar TS-1651 Soldering Kit shown here, you get the soldering iron, a stand (to hold it when it's hot), some resin-cored solder wire and even a solder sucker to suck up solder if you make a mistake and need to unsolder a component.

Small side cutters or "nippers" are almost essential. You use them to trim off the excess component leads, cut wire links to length, remove outer insulation from cables and so on. These are the Jaycar TH-1890 cutters, which are 115mm long.



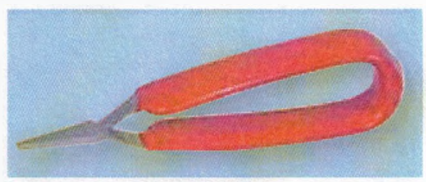
Small long-nose pliers are also very useful for jobs like bending component leads correctly, forming wire links and also holding small items like nuts in confined spaces. The Jaycar TH-1893 pliers shown here are spring-loaded and just the shot for most electronics work.

A properly designed wire stripper makes removing insulation from wires much easier, faster and safer. The Jaycar TH-1824 stripper shown here automatically adjusts to the insulation diameter and is well worth adding to your toolbox.



A PC board holder can make things much easier when you're soldering components to a printed circuit board, holding it in place while leaving both of your hands free to hold the solder and the hot iron: an artificial 'third hand'! This is the Jaycar TH-1983, which is easily adjustable, has a magnifying glass and features a solid cast-iron base for stability.

A clip-on heatsink is handy when you're soldering small components, especially semiconductors. It prevents overheating by drawing the heat away from the body – and frees up your hands as well! This Jaycar TD-2122 is low in cost but all you need.



Pointed-end tweezers can help hold wires and component leads while you're soldering them, or small nuts while you're trying to fit them to screws. The low-cost Jaycar TH-1754 tweezers shown here are a good choice. ★

Your Multimeter...

Multimeters make great tools for checking how well a circuit is operating— or for tracking down the cause of the problem, if it *isn't* working. But there are some basic DOs and DON'Ts to bear in mind, to make sure you take accurate measurements and don't risk damaging either your meter or the circuit you're testing. Follow this easy pictorial guide and you shouldn't strike any problems.

The main thing to remember when you're using a multimeter is that before you connect its probes to the circuit or component to be tested, make sure you have:

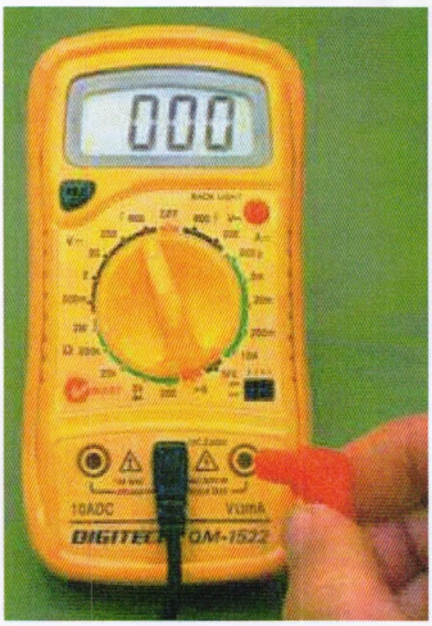
(a) Set it for the correct KIND of measurement — in the main, VOLTS DC if you're measuring DC voltages; VOLTS AC if you're measuring AC voltages or you are not sure whether the voltage is AC or DC; AMPS (or more likely, MILLIAMPS) if you're measuring current; or OHMS if you're measuring resistance.

(b) Set the right range — that is, a range higher than the highest voltage, current or resistance you expect to be measuring. If you don't know, select the highest range available.

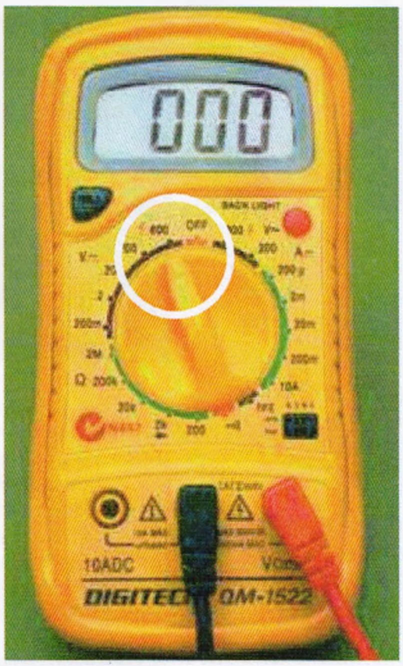
(c) Plugged the probe leads into the correct sockets on the meter itself, for that kind of measurement and range.

For checking any of the circuits and components in this book (and in fact for most electronics work), a digital multimeter (DMM) or an analog type (as shown above right) are equally suitable. A wide range of digital multimeters is available from Jaycar Electronics stores, along with the QM-1020 analog multimeter shown above.

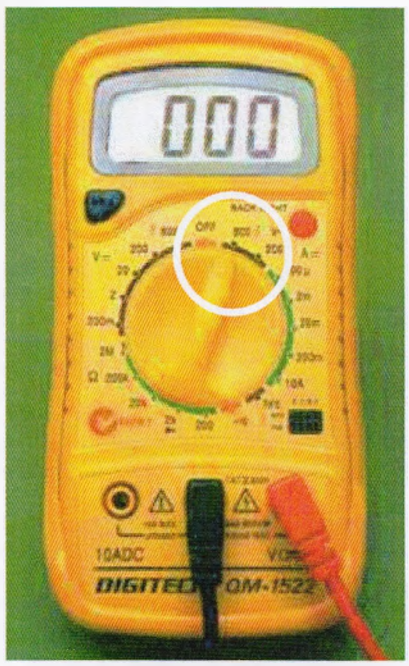
If you don't check these points, there could be an expensive BANG when the probes touch that circuit or component!



For most measurements, the black probe lead's plug goes into the multimeter's COM (common) socket, and the red lead's plug goes into the V-Ω-mA socket. Push them into the sockets as far as they'll go, to make sure there's a good connection and no exposed metal (which could allow accidental shocks if you're measuring high voltage).



Before measuring a DC voltage, set the meter to its highest DC voltage range (here 600V). That way, there shouldn't be any damage done if the voltage is higher than you expect. You can always click down a range or two to take the measurement more accurately, if you need to.

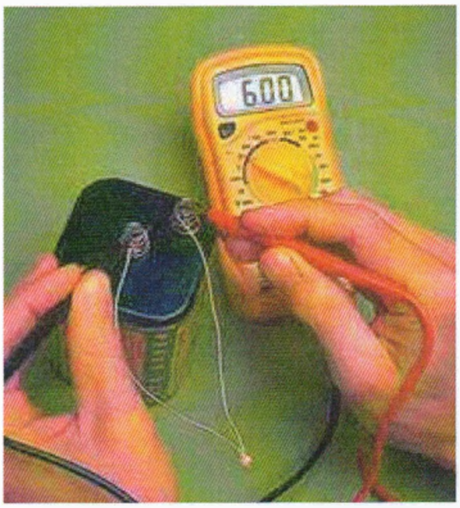


The same applies when you're about to measure an AC voltage — set the meter to its highest AC voltage range first, to avoid mishaps. Here the switch is set to 600V again, but this time on the AC voltage ranges (the V with a ~, a small sinewave 'wiggle', indicates AC voltage).

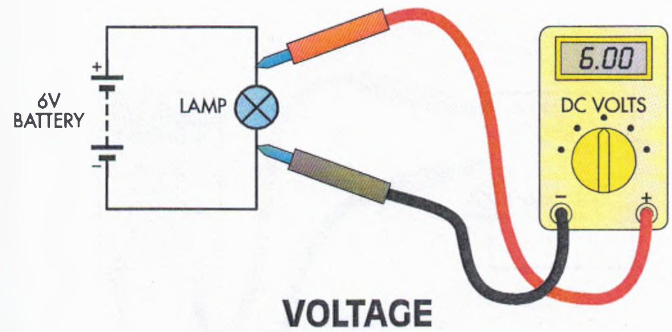
and how to use it

Measuring VOLTAGE — volts (V) and sometimes millivolts (mV)

Voltage is measured by connecting the meter across the component or circuit under test while power is connected. In other words, the meter is in PARALLEL with the circuit or part of the circuit under test.

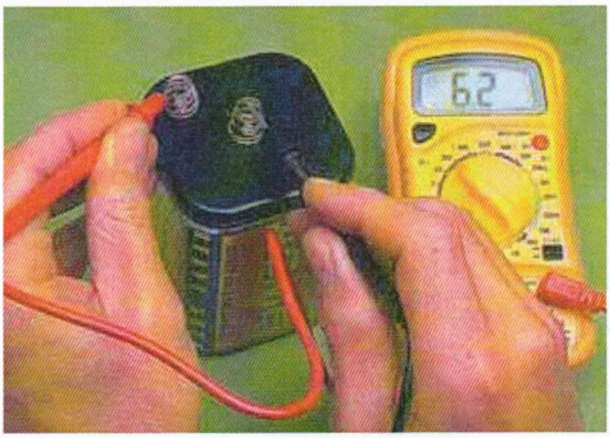


When you're measuring voltage (also known as potential difference), the two meter probes are simply connected between the two points concerned — such as the terminals of a battery or the terminals of a lamp.

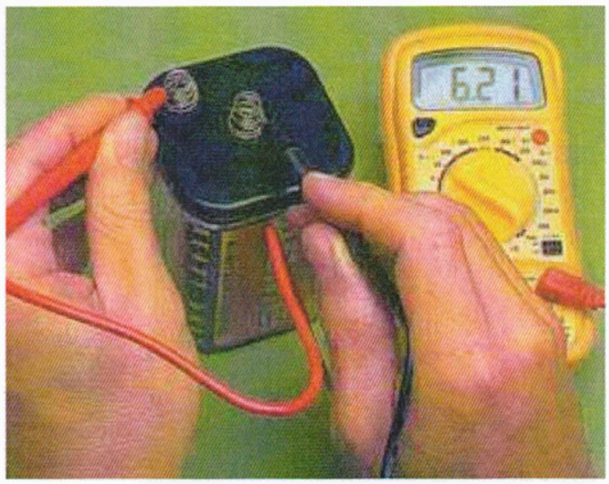


VOLTAGE

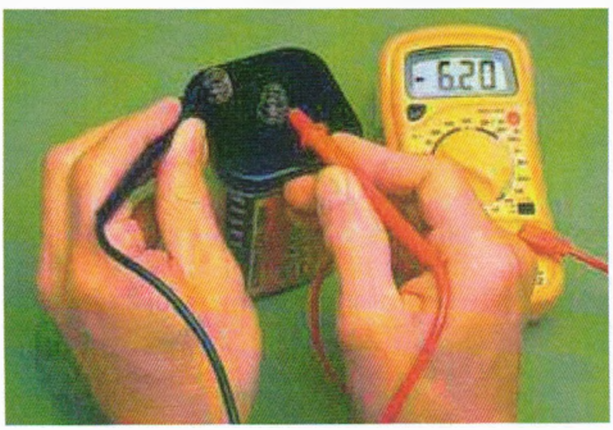
METER IN PARALLEL WITH COMPONENT UNDER TEST



Let's start by measuring the terminal voltage of a battery. Turning the knob from 'OFF' to any other position (in this case the 200V DC range) also turns the digital multimeter on. Connect the red (positive) meter probe to the positive battery terminal and the black (negative) meter probe to the negative battery terminal. Here a fresh lantern battery reads just over 6V.



Since we now know the reading is below the maximum limit of the next range down (ie, 6V is less than 20V), we can click the knob to that range and the reading will be one digit more accurate. Note that it now says 6.21V, instead of of 6.2V. Sometimes that extra accuracy is very important.

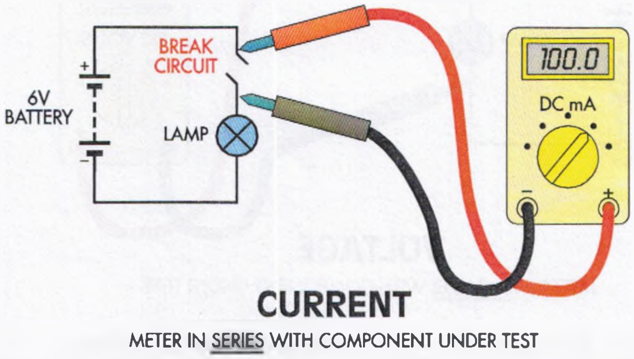


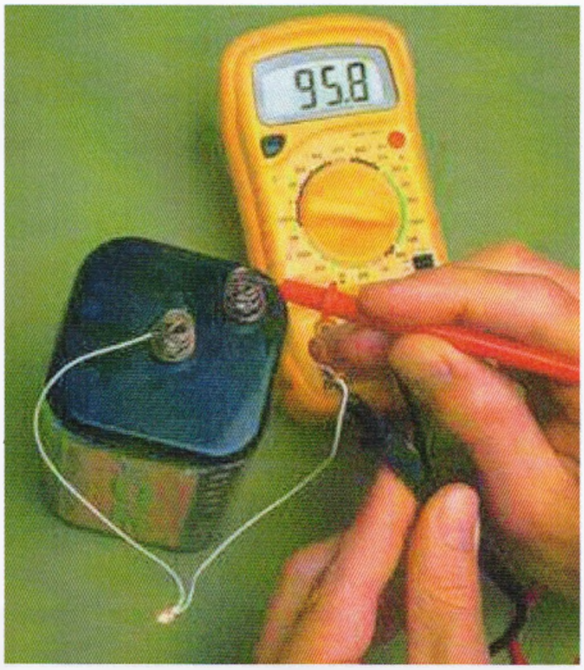
If you accidentally connect a digital multimeter's test probes to the battery terminals the wrong way around (ie, red to negative, black to positive), it will still read the correct voltage — but with a minus sign to show the reversed polarity. No harm done — but it's important to know what that minus sign means. With an analog meter you should never connect the probes back to front, because it may be damaged.

Measuring CURRENT — amps (A), milliamps (mA) or microamps (μA)

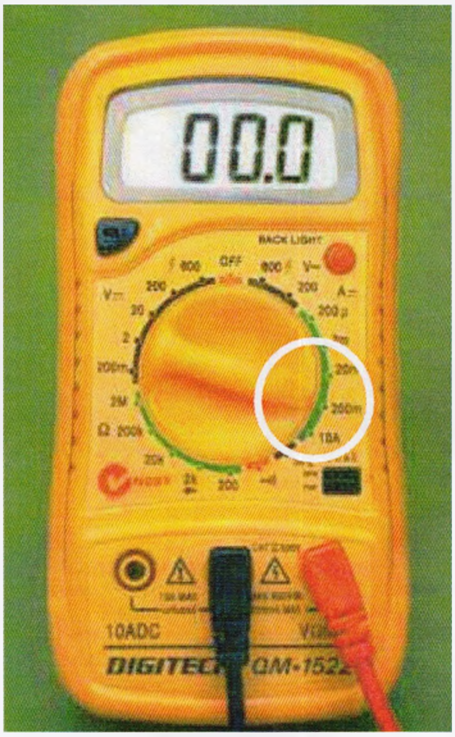
Current is measured by making the current flow out of the circuit, through the meter and then back into the circuit again. In other words, the meter is connected in SERIES with the circuit or part of the circuit under test.

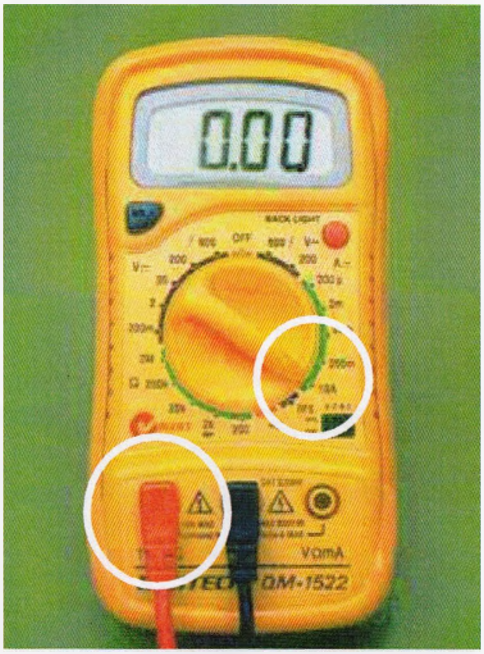
When you want to measure the current in a circuit, you need to break the circuit at that point and connect the probes so that the current to be measured flows THROUGH the meter — which must be switched to the correct current range, of course. Here the small lamp is seen to be drawing close to 100mA.





When you are going to measure a current, it's again important to switch to a higher range than you expect before connecting the meter into circuit, to prevent accidental overloads. Here (below) the meter has been switched to the 200mA range, before making the measurement of lamp current — because, according to the manufacturer's data, the lamp should draw about 100mA from a 6V supply.



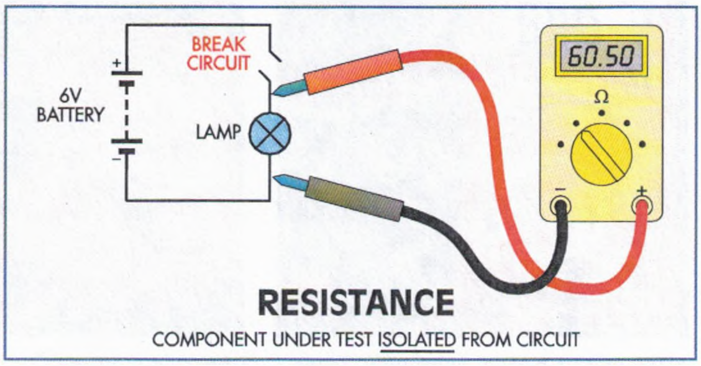


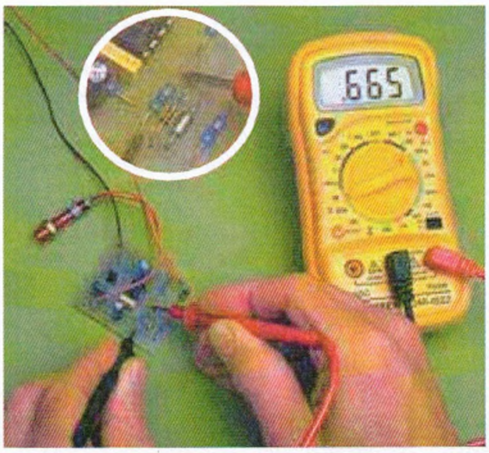
With many multimeters, the red (positive) probe lead needs to be changed over to a special 'high current' socket before you can measure currents of more than a few hundred milliamps — as well as switching to the appropriate higher current range. Here (above) the red lead has been plugged into the meter's '10A DC' socket on the left hand side, to measure currents up to 10A. Just remember to change the red lead back to the 'V-Ω-mA' socket before you try to make any other kinds of measurement, or there could be an expensive BANG!

Measuring RESISTANCE — ohms (Ω), kilohms (kΩ) and megohms (MΩ)

Resistance is measured by passing a tiny current (provided by a battery inside the meter) through the component under test. The component must be isolated from other components and any other source of current, as this would upset the measurement — and could even damage the meter.

When you switch to any of the resistance ranges on a DMM and before you make a measurement, it generally gives the kind of 'over range' indication shown at left when there's no connection between the probes. If it doesn't, the battery inside the meter may need replacing.





Although you can measure the value of resistors that are soldered into a PC board by simply connecting the meter probes across them, this can give a false and lower reading because the board's tracks may be connecting other components in parallel with them. Here (left) a 1MΩ resistor is reading only 665kΩ, because of this problem.

To make an accurate measurement of a resistor on a PC board, one end should be carefully unsoldered from under the board and lifted so the meter can measure just the resistor by itself. As you can see on the right, the 1MΩ resistor is now measuring 999kΩ — which is well within its tolerance.

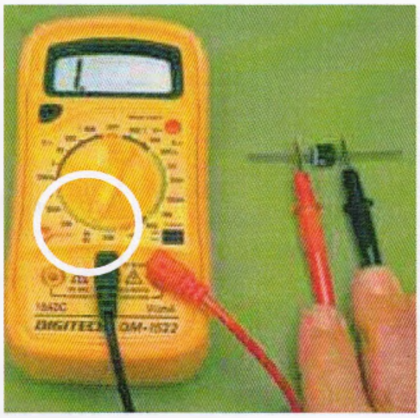
When you're trying to measure fairly high resistances, make sure you don't cause errors by connecting yourself in parallel with the probes. As you can see on the left, the human body is not a good insulator; here the resistance between the user's hands reads only 1.51MΩ.

With the user's hands well back from the probe tips and behind the guard rings on the plastic sleeves (which is the correct position for safety, in all measurements), the meter now reads 'over range' — as it should, with an open circuit between the probes.

Other ranges: diode/transistor checking, continuity, etc

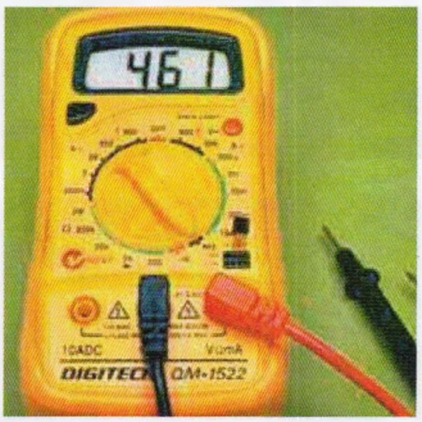
Many modern meters, even low cost models, have a handy selection of other ranges which are used to check other components — semiconductors, especially. Some also have inbuilt buzzers to help check continuity. Here's how to make these measurements.

Many meters have a 'continuity' range, a low resistance setting which is used to check for breaks in cables and PC board tracks. When the two probes are touched together (or connected via a low-resistance circuit such as a cable conductor), the meter reads the approximate resistance between them. A buzzer or beeper may also sound, so you don't have to look at the meter to know that the circuit is OK.

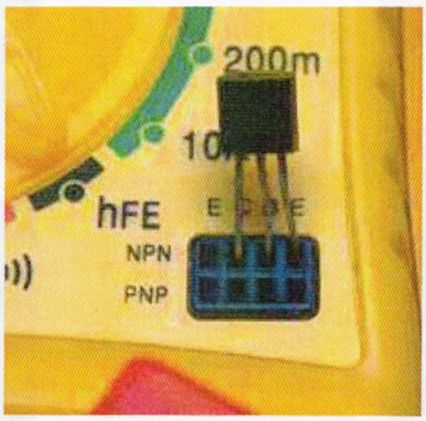


Checking the forward conduction of a silicon diode is very easy using the 'diode check' function. With the switch in the diode position, you simply connect the test probes across the diode one way and then the other. Here the positive (red) probe is on the cathode (striped) end, which reverse biases the diode. The meter reads '1' or over-range, just as a reverse-biased diode should read.

Reversing the probes (or the diode itself as shown here) forward biases the diode, with the meter now reading its voltage drop for a specified small forward current. Here the silicon power diode has a drop of 0.741V, showing that it's fine. Silicon diodes can be expected to show a forward voltage drop of between about 0.5V and 0.8V in this test, depending on their type. Higher voltages may indicate a fault.



Many multimeters can also be used to measure the current gain (also called the h_{FE} or 'beta') of bipolar transistors. In most cases, it's just a matter of switching the meter to the h_{FE} range and plugging the transistor into a multi-way transistor socket on the meter's front panel.



Just how the transistor is plugged into the meter to measure h_{FE} depends on whether it's an NPN or PNP type, and on the way its 'works' are connected to the three leads. As you can see both rows of holes have an emitter (E) socket at both ends, to allow for almost any possible combination of lead connections.

With the transistor plugged in correctly, the meter reads its h_{FE} current gain directly (in this case 461). If you get a very low reading, the transistor may be a dud, or you might have accidentally swapped the collector and emitter connections. If changing these connections over gives a much higher reading, that was the problem and your transistor is OK.

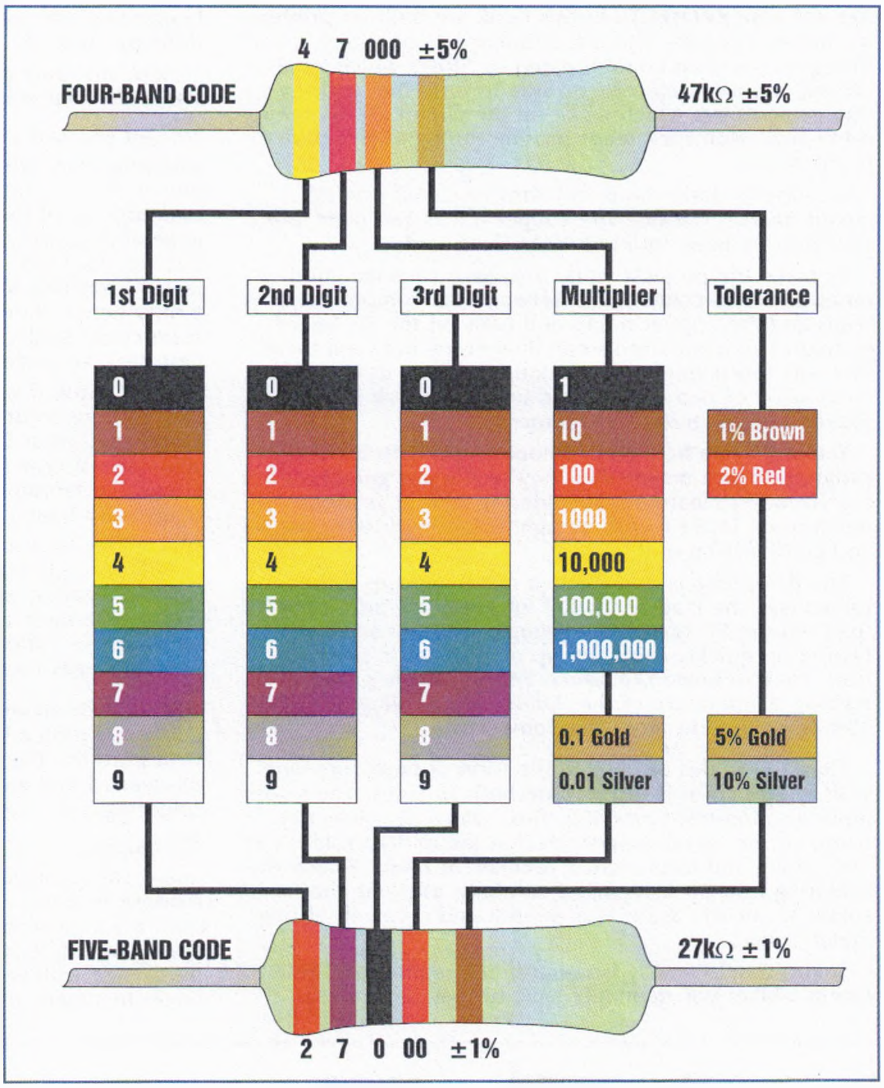
Resistors & their Colour Coding

Resistors are one of the most common components in electronic circuits, but many of their bodies are too small to carry their **nominal value** and **tolerance** (or margin of error) printed in numerals. To get around this problem, a system of using tiny bands of coloured paint has been used for many years. Each colour band is used to represent either a numeral, or a particular decimal multiplier, so it's generally not too hard to work out the value of a resistor by checking its 'colour code' (see drawing at right).

The bands are normally nearer one end of the resistor than the other, and they're read from that end. What can make things a little confusing is that most modern resistors can have either four or five bands in all. With a four-band type, the first two bands show the basic value (there are only 12 possibilities for this type, in each 1:10 range or **decade** — see table), while the third band shows the 'number of noughts' (i.e., the decade it's in) and the fourth band (often spaced slightly further away) shows the **tolerance** — how close to the specified 'nominal value' the actual value is likely to be.

Preferred Resistor Values
(in each decade or 1:10 range)

E6 Series (20% Tolerance)	E12 Series (10% Tolerance)	E24 Series (5% Tolerance)
10	10	10
		11
	12	12
		13
15	15	15
		16
	18	18
		20
22	22	22
		24
	27	27
		30
33	33	33
		36
	39	39
		43
47	47	47
		51
	56	56
		62
68	68	68
		75
	82	82
		91



Use the diagram above to work out the value of any resistors you find in a project kit. The examples show resistors with 4-band (top) and 5-band codes (above).

With five-band resistors, which can have 24 possible values in each decade (they're generally of closer tolerance), the first three bands can be used to show the basic value — even though in most cases only the first two are really needed, and the third band is set to black (meaning '0'). In this case the fourth band signifies 'the rest of the noughts', to indicate the decade, and the fifth band gives the tolerance.

Note that the '0' represented by a black third band on a five-band resistor doesn't mean it can be ignored. That nought is still counted, so that a black third band followed by a red fourth band means there are THREE noughts — the equivalent of an orange third band on a four-band resistor (see lower example).

Sometimes the body of the resistor can have a colour which makes it hard to decide the exact colour of some bands by eye. The best plan here is to check the resistor value with a multimeter, before wiring it into your circuit. The same applies if the bands seem to be equally spaced from both ends, so you don't know which end to start from. Where there's a gold or silver band, though, this will often help you work that one out — because these bands always go at the end of the code. ★

Soldering: How it's done

ALL OF THE PROJECTS in this book are built on printed circuit (PC) boards. These are thin sheets of epoxy fibreglass (or resin bonded paper — SRBP) which have etched copper tracks on one side to form the 'wiring'. The components which make up the circuit are on the other side, with their leads passing through holes drilled in the board.

It's easy to understand why they're called *printed circuit boards*, because the copper tracks and pads look as if they've been 'printed' onto the board.

To make the projects work, you have to make good metal-to-metal connections between the component leads and the copper tracks and pads on the PC board, so that electrical currents can flow easily between them. The way this is done is by making the joins using **solder** — an alloy of two metals (lead and tin) which is easily melted at a relatively low temperature.

You'll need to be able to solder properly to build these projects. Which means that they're not just good fun, but a great way to learn about soldering as well as about electronics. Don't worry, though; soldering is easy once you get the hang of it.

The basic idea is that the two metal surfaces to be joined (say the lead or 'pigtail' of a resistor, and a copper 'pad' on the PC board) are brought together and both heated up quickly using the tip of an electric soldering iron. They're heated to above 183°C, which is the melting temperature of the '60/40' solder alloy (60% tin, 40% lead) used in most electronic work.

Then the solder (usually in the form of fairly fine wire with a resin core) is touched on both surfaces. The solder melts and the resin acts as a 'flux' which dissolves any oxide on the metal surfaces so that the molten solder can 'wet' them and form a good permanent bond. Finally the soldering iron tip is removed carefully, allowing the solder to solidify again as a smooth and relatively strong metal 'joint'.

Sound easy? It really isn't hard, although it is a bit like riding a bike: you generally have to practice a while before you can make good solder joints without even thinking about it.

Here are some practical tips, to get you off to a good start with your soldering:

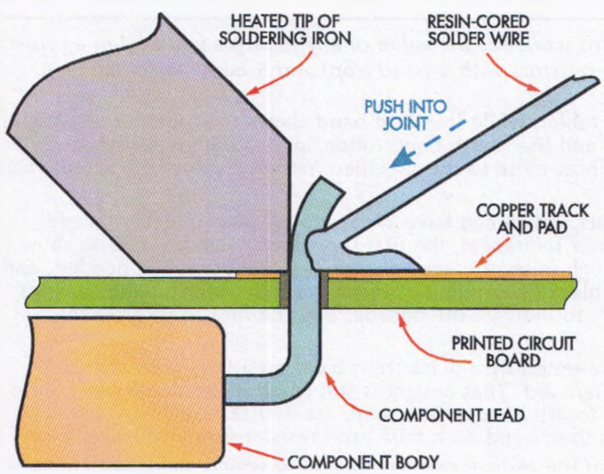
① Get yourself a good lightweight 'electronics' type soldering iron, with a small tip and not too much heating power. An iron rated at 25 watts is more than enough for building any of the projects in this book, and most general electronics work. A good example is the Jaycar Cat No. TS-1465. This is also available as part of the Jaycar Soldering Kit TS-1650, which comes complete with a nifty bench stand/holster, a tip cleaning sponge, some resin-cored solder and even some 'solder wick' braid to help remove solder when you need to.

Even better, if your budget will stretch that far, is a temperature controlled soldering station like the Duratech (Jaycar Cat No. TS-1380). This has a professional-type low voltage soldering iron with an adjustable thermostat to control tip temperature, plus a really solid bench stand and cleaning sponge, etc.

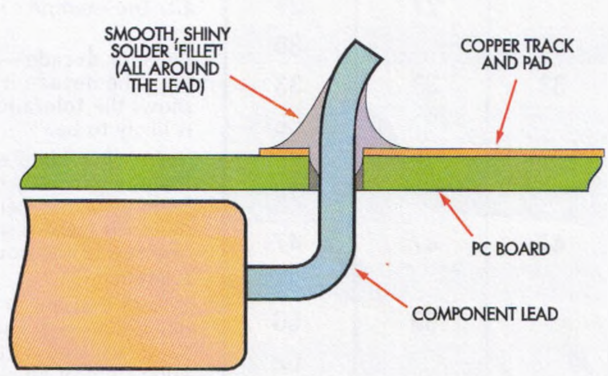
Don't try to use a heavyweight plumber's soldering iron — it'll not only make your arm and hand tired, but also risk overheating your delicate electronic parts and PC board. The same applies to gas-fired soldering torches and irons — although when you get skilled, one of the very small gas-fired soldering pencils is OK.

② Any two metal surfaces to be soldered need to be clean and preferably already 'tinned' — either plated with pure tin, like the leads of many modern components or cleaned and given a thin coating of solder using a soldering iron and solder.

③ The tip of your soldering iron also needs to be clean, and it should have a coating of tin or solder. Most modern iron tips are tin plated, but before making each joint it's a good idea to clean off any oxide, burnt flux etc by wiping it over a small piece of sponge which is moistened with water. The hot tip turns some of the water to steam, which in turn 'steam cleans' the iron tip.



1: How to solder a component lead to its PC board pad. The tip of the iron heats both the lead and the copper pad, so the end of the solder wire melts when it's pushed into contact with them.



2: A good solder joint. Notice that it has a smooth and shiny 'fillet' of solder metal, bonding all around to both the component lead and the copper pad of the PC board. This joint provides a reliable electrical connection.

About Lead-free Soldering

Because the lead in traditional tin-lead solder is considered by some to be quite toxic, the world's electronics industries are in the process of changing over to **lead-free solder** in an effort to increase safety and reduce environmental pollution.

If you decide to use lead-free solder when you are building electronics projects, be aware that because this solder has a higher melting point (240°C) than traditional tin-lead solder, you'll need to set your soldering iron for this higher operating temperature.

Just be careful not to overheat the components when you're soldering their leads at this higher temperature. 'Speed with care' is still the motto.

④ Make sure the soldering iron tip has reached the correct temperature. If it isn't hot enough, you won't be able to make a good joint. If you're using a soldering station or iron with a thermostat, this usually begins making a ticking sound when the correct temperature is reached. Otherwise, try touching the end of the solder wire against the (cleaned) tip — it should melt and flow easily.

⑤ Try to touch the iron tip to both metal surfaces together, so they both heat up to soldering temperature in the shortest time. Otherwise one might get too hot before the other gets hot enough. This can cause damage to delicate components like ICs, and it may also overheat the PC board copper pad so that it lifts away from the board.

⑥ Almost immediately after applying the iron tip, touch the end of the solder wire to both metal surfaces. That way, the solder itself will melt and run into the joint the instant the right temperature has been reached. Push just enough solder into the joint to flow a nice 'fillet' of molten solder around the two surfaces, then remove the solder. Finally move the iron away too, taking care not to bump the joint before the solder solidifies again.

Mind you, you'll solder each joint much quicker than the time it took to read the above lines of text. The secret of good soldering is to do it quickly — heat up the joint, touch the solder to it so that it wets both metal surfaces and flows nicely, then pull the solder and the iron away without bumping the joint as it solidifies. It takes just a second or two to make each connection.

If the solder doesn't seem to want to melt against one of the metal surfaces, a good trick is to brush the end of the solder wire against the tip of the iron — so it starts to melt and flow between the surfaces. The molten solder itself will help bring the two metal surfaces up to temperature and 'start the ball rolling'.

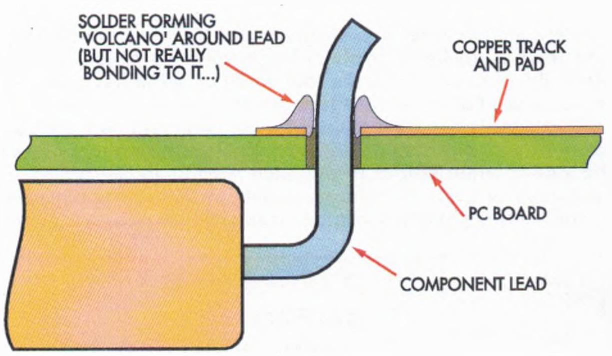
⑦ As we've already said, try to make the joint as quickly as possible because the longer you take, the higher the risk that the component itself and the PCB pad and track will overheat and be damaged. But don't work so quickly that you can't make a good joint — having to do it over again will also increase the risk of damage. So 'speed with care' is the motto.

⑧ As the solder solidifies, take a careful look at the joint you've made, to make sure there's a smooth and fairly shiny metal 'fillet' around it. This should be broadly concave in shape, showing that the solder has formed a good bond to both metal surfaces. If it has a rough and dull surface or just forms a 'ball' on the component lead, or a 'volcano' on the PCB pad with the lead emerging from the 'crater', you have a 'dry joint'. This will have to be done again — perhaps after cleaning one of the metal surfaces again. See the drawings for what you need to look for.

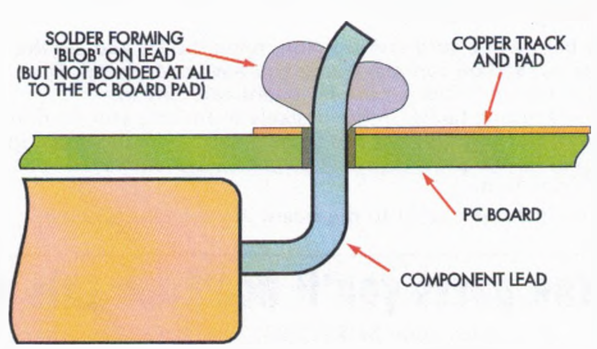
⑨ For projects that use one or more ICs, with their closely-spaced pins, you may find it easier to use fairly fine gauge solder (less than 1mm diameter). This reduces the risk of applying too much solder to each joint, and accidentally forming 'bridges' between pads or tracks.

Well, that's the basics of soldering. But if you're new to soldering, why not get in a bit of practice before you start work on your first real project? Find yourself a piece of old PC board and a few surplus resistors or bits of hookup wire, and try making a few solder joints. You'll soon get the hang of it.

By the way when you get a little further into electronics, you'll also need to know how to **desolder**. You'll find more about this on page 133. ★



3: One kind of 'dry' joint. As you can see, the solder has bonded to the PC board pad, but isn't bonded at all to the component lead. It'll cause trouble if it isn't re-soldered properly, so that it looks like drawing 2.



4: Another kind of dry joint. Here the solder has bonded to the component lead, but not to the PC board pad. Again it needs to be re-done to look like drawing 2, because there's no reliable electrical contact.

Project 3:

A Hee-Haw Siren with Flashing LEDs

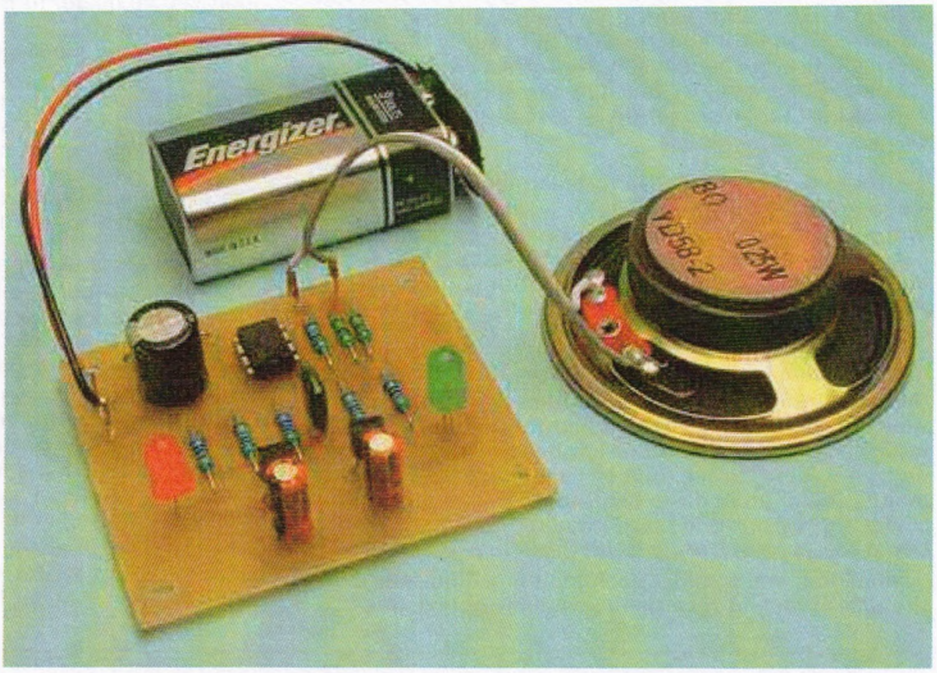
Here's a project which generates a 'hee-haw' siren sound just like an emergency vehicle. That's not all, though. As a bonus it also flashes a red LED and a green LED alternately, in time with the siren's sound. This makes it really great for grabbing anyone's attention, so you can use it for things like a simple intruder alarm for your bedroom — or dad's garden shed.

What does it do?

At the heart of the siren is a low cost 555 timer IC, the same type we used in Project 1 to flash the LEDs. But this time we're using it as an oscillator to make the siren sound, when its output signal is fed to a small speaker.

For a change, we're using a simple two-transistor '**multivibrator**' oscillator to flash the LEDs. We also use the output of the multivibrator to vary the frequency of the 555 oscillator, and this is how we make it produce the up-down or 'hee-haw' sound.

Apart from the 555 timer IC the complete project uses only two very low cost PN100 transistors and a handful of small parts, plus a 57mm mini speaker to produce the sound output. As usual the project is powered from a standard 9V battery, and everything apart from the battery and speaker fits on a compact PC board (code SHRTC203) measuring only 57 x 51mm. This makes it very easy to build, so let's go!



Putting it together

Just before you start construction, open the kit and lay the parts out so you can make sure you have everything. Then check the underside of the PC board carefully for manufacturing faults. In the unlikely event that you do find a broken track or a solder bridge between tracks, it should be easy to fix the problem quickly at this stage with your soldering iron.

The first items to fit to the board are the four terminal pins. Two of these go where the battery clip lead wires connect, and the other two where the speaker wires connect.

There are no wire links to fit on this board, so once the pins have been fitted you can begin with the resistors. There are eight of these, but note that some of them have the same value. For example there are three with a value of 100k ohms, two with a value of 470 ohms and two with a value of 150 ohms. So it's especially important not to mix up the values when you're fitting each resistor to the board. Each resistor's value is shown clearly in the wiring diagram, so follow this closely as well as using the photos as a guide.

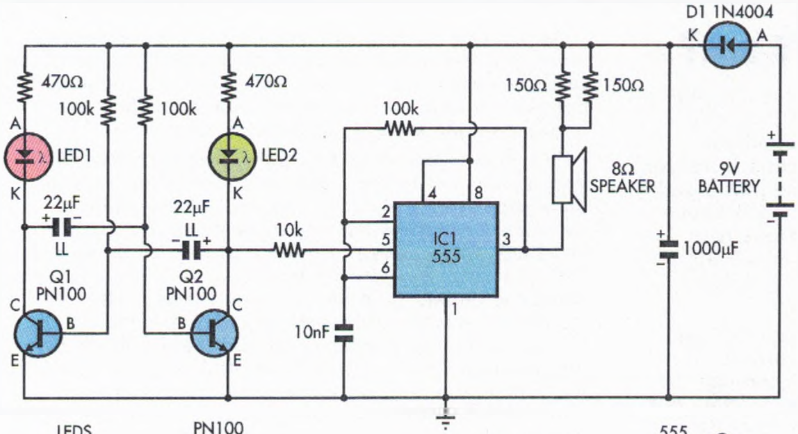
The parts you'll need for this project:

1 PC board, code SHRTC203, 57 x 51mm
4 PCB terminal pins, 1mm dia.
1 57mm mini speaker
1 9V battery, 216 type
1 Battery clip lead to suit
1 Short length of speaker lead
1 Small pack of resin-cored solder

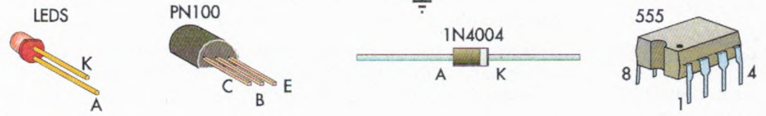
Semiconductors
1 555 timer (IC1)
2 PN100 transistor (Q1,Q2)
1 5mm red LED (LED1)
1 5mm green LED (LED2)
1 1N4004 diode (D1)

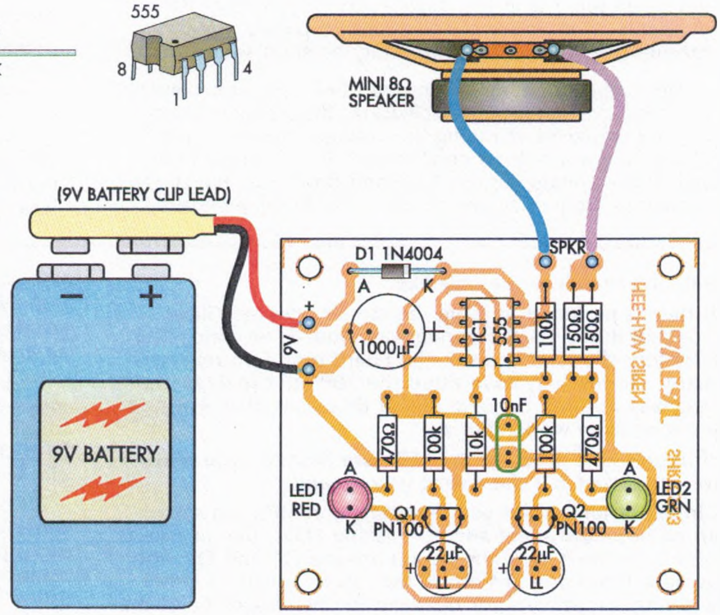
Capacitors
1 1000µF 16V RB electrolytic
2 22µF 25V RBLL electrolytic
1 10nF greencap

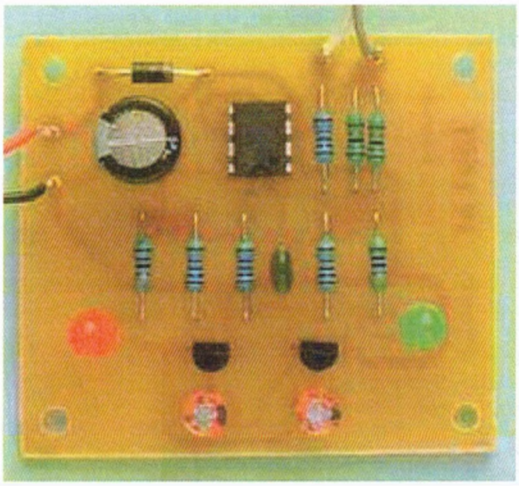
Resistors (0.25W 1%)
3 100k
1 10k
2 470 ohms
2 150 ohms



Here's both the circuit diagram (left) and the wiring diagram (below) for the siren/flasher, plus a closeup photo of the PC board as well at lower left. Use all of these as a guide when you're building your own. Take special care when you're fitting all of the polarised parts to the board: the diode, the LEDs, the IC, the transistors and the electrolytic capacitors.







As usual it's a good idea to fit the resistors so their colour codes all read the same way, even though resistors are not electrically polarised. This gives a professional look.

With the resistors fitted, you can fit the remaining non-polarised component: the 10nF greencap capacitor, which goes in almost the exact centre of the board. It too can go either way around, but notice that the board has two alternative holes for one of its lead wires. Use whichever one best suits the lead spacing of your particular capacitor.

Next to fit are the three electrolytic capacitors, the first of the polarised parts. These all fit on the board with their positive side towards the right and their negative 'striped' side towards the left, as you can see from the wiring diagram and the photos. Again the board provides a choice of holes for each one, to suit different lead spacings.

Be especially careful with the two smaller 22μF capacitors, though, because the three holes for each one are all spaced 2.5mm apart. Make sure that you fit each capacitor with its negative lead through the leftmost hole of the three.

Now you can add the semiconductor devices, starting with diode D1. Make sure this has the cathode 'band' end towards the right, as shown in the wiring diagram. Then fit the two PN100 transistors Q1 and Q2. As you can see these both fit with their 'flat' side uppermost, towards the back of the board. Their leads are all kept in line, but you'll have to crank both outer leads away from the centre lead to allow them all to pass through the board holes easily.

Next you can fit IC1, and as shown in the wiring diagram this should be fitted with its notch/dimple end downwards towards the front of the board.

The last components to fit are the two LEDs, with the red LED on the left and the green LED on the right. (Although you can swap them if you wish.) Both mount with their 'flat' cathode side downwards, as you can see. You can fit them with their bodies about 6mm above the board, as in the photos, or with them further from the board if you prefer.

Finally, connect the wires of the battery clip lead to the terminal pins on the left-hand side of the board. Also connect up the speaker to the two pins on the back of the board, using a couple of short lengths of insulated hookup wire. Your Hee-Haw Siren with Flashing LEDs should then be complete and ready to go.

Trying it out

There are no adjustments to make on this project, so it should start making the hee-haw siren sound and flashing the LEDs as soon as you connect the clip lead to the battery. One LED glows during the 'hee' part of the siren sound, while the other LED glows during the 'haw' part.

But what do you do if *your* siren/flasher doesn't show any sign of life when you connect the battery? Or if it starts making a continuous sound from the speaker, with no hee-haw effect? Or if the LEDs don't flash, but instead one or both of them either stays off or on? Well, any of these problems indicates that you've made a mistake in wiring up the siren/flasher. So the next step is to disconnect the battery

Tech Talk: How does it work?

The heart of the siren section of the project is IC1, the same low cost 555 timer IC that we used in Project 1 — and used here in exactly the same type of oscillator circuit. It oscillates because of the 100k feedback resistor connected from output pin 3 back to sensing pins 2 and 6, together with the 10nF capacitor connected between pins 2 and 6 and the negative supply rail. These two components control the basic frequency at which IC1 oscillates, and when it oscillates output pin 3 switches rapidly up and down between +9V and 0V.

Because the speaker is connected between pin 3 and the +9V supply rail, via the two 150 ohm current limiting resistors, current can therefore flow through the speaker when pin 3 is at the 'low' (0V) voltage level, but not when pin 3 is at the 'high' (+9V) level. So as IC1 oscillates, a sequence of short current pulses pass through the speaker — generating the siren sound.

Although the 100k resistor and 10nF capacitor control IC1's basic frequency of oscillation, the frequency can also be varied by changing the voltage applied to pin 5 of the IC (known as its control pin). In this project we switch the voltage on pin 5 up and down, to change the oscillating frequency and produce the hee-haw effect.

As you can see from the circuit pin 5 is connected through a 10k resistor to the collector of Q2, one of the two transistors. And the two transistors are connected together to form what is known as a *multivibrator* — another simple kind of oscillator circuit.

In a multivibrator the two transistors each have their base connected to the collector of the other transistor via a capacitor. This 'cross coupled' arrangement is unstable, because when one transistor turns on and conducts, this causes the other transistor to be turned off. As a result they switch back and forth, with first one transistor on and then the other on instead. The frequency at which this switching occurs is mainly controlled by the coupling capacitor values (here 22μF) and the base bias resistors (here 100k). Larger values for these components give a lower switching frequency, while smaller values give a higher frequency. The values shown give a switching frequency of about 0.5 hertz.

Here the two transistors each have a LED connected in series with their collector resistor, so that when each transistor conducts it turns on that LED. This produces the flashing LEDs. Then by connecting the collector of Q2 to pin 5 of IC1 via the 10k resistor, we also make the frequency of IC1's oscillation vary up and down as the multivibrator switches. This is how we produce the hee-haw effect.

again, and search for the mistake.

If there's no life at all from the circuit, you may have connected diode D1 the wrong way around, or connected the battery clip lead wires to the board pins with reversed polarity. Or you may have fitted the 1000μF capacitor the wrong way around, because any of these mistakes will stop the circuit from working at all.

If there's no sound but the LEDs are flashing, you may have connected IC1 the wrong way around.

On the other hand if you're getting a continuous sound with no hee-haw effect and no flashing LEDs, the mistake is probably in the part of the circuit around Q1 and Q2. You may have fitted one or both of the 22μF capacitors either the wrong way around, or between the two board holes that are shorted together (which results in the capacitor not being connected into the circuit). Or you may have connected one or both of the transistors around the wrong way, or one or both LEDs. (This could have damaged them.)

If you check out each of these possible mistakes carefully, comparing your board with the wiring diagram, you're almost certain to find the problem in short order. Then it's simply a matter of fixing the wiring mistake and connecting up the battery to try it again. Resistors, capacitors and most diodes are pretty forgiving.

What to do next

If you'd like to change the pitch of the siren's sound, this can be done quite easily by replacing the 10nF greencap capacitor with one of a higher or lower value. A lower value capacitor like 8.2nF or 6.8nF will give a higher pitched (more shrill) sound, while a higher value like 15nF or 22nF will give a lower pitched (deeper) sound. So feel free to experiment.

It's also quite easy to vary the hee-haw and LED flashing rate, by replacing the two 22μF electrolytic capacitors with others of higher or lower value. For example if you replace them with 33μF capacitors this will slow down the hee-haw rate, while replacing them with 15μF capacitors this will speed things up and give a more 'urgent' sound.

You might want to house the siren/flasher in a plastic box, to protect it from damage. The board assembly, mini speaker and battery will all fit easily inside a standard UB3 size plastic jiffy box, such as the Jaycar HB-6023 (grey) or HB-6013 (black). The board assembly can be mounted inside the box itself, using four 15mm long M3 machine screws (HP-0406) and nuts (HP-0425), with 9mm metal spacers (HP-0862) between the board and the box rear. The mini speaker can then be glued on the rear of the box lid, behind an array of 8mm holes to let the sound out.

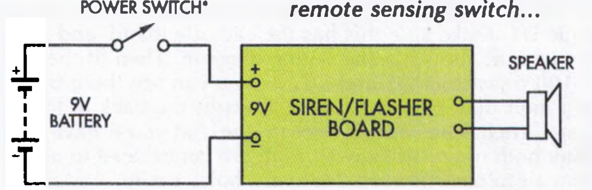
If you do mount the siren/flasher in a box like this, you might also like to fit it with an on-off switch. A simple mini toggle switch is all that's needed, such as the Jaycar ST-0335. It's simply wired in series with one of the battery clip leads.

Of course if you want to use the siren/flasher as an intruder alarm, you'd use a remote door or window switch as its power switch — so when the door or window is opened, the siren 'goes off'. In this case the type of switch you'd use would be something like the Jaycar LA-5066 tamper switch or the SM-1040 microswitch, connected up to the siren via a length of light-duty 'figure 8' cable such as Jaycar's WB-1560 or WB-1702. The switch would be wired so its contacts are 'open' when the door or window is closed, and only close the circuit when the someone opens the door or window.

Finally if you'd like the siren to produce a louder sound, the easiest way to do this is to replace the kit's mini speaker with a more efficient horn speaker like the Jaycar AS-3180. In addition you can replace the two 150 ohm resistors with a pair of 82 ohm resistors, so the speaker is able to draw more current. However if you **do** change these resistors, the small 9V battery will have to be replaced with one capable of delivering more current as well. A suitable replacement would be six AA alkaline cells, mounted in a six-cell holder like the Jaycar PH-9206.

By the way, don't lower the output resistors below that suggested lower value of 82 ohms. This would allow the speaker to draw more current than the 555 timer IC can handle, and it would almost certainly be damaged.

How to connect a power or remote sensing switch...



Chapter : UEEEC0060: Repairs basic electronic apparatus faults by replacement of components: 7.6 Performance data cables
Book Title: UEEEC0060: Repairs basic electronic apparatus faults by replacement of components
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7.6 Performance data cables

Data is the information being transferred along a cable or processed by a device. Data is made up of ones and zeros and each is called a bit of data. The word bit is derived from **bi**nary digi**t**.

Data bits are grouped together in sets called a byte. A byte has eight bits. The bits are transmitted together and are read by the processor in groups of 8. The 1s and 0s can be placed in 256 different combinations within the eight-bit byte.

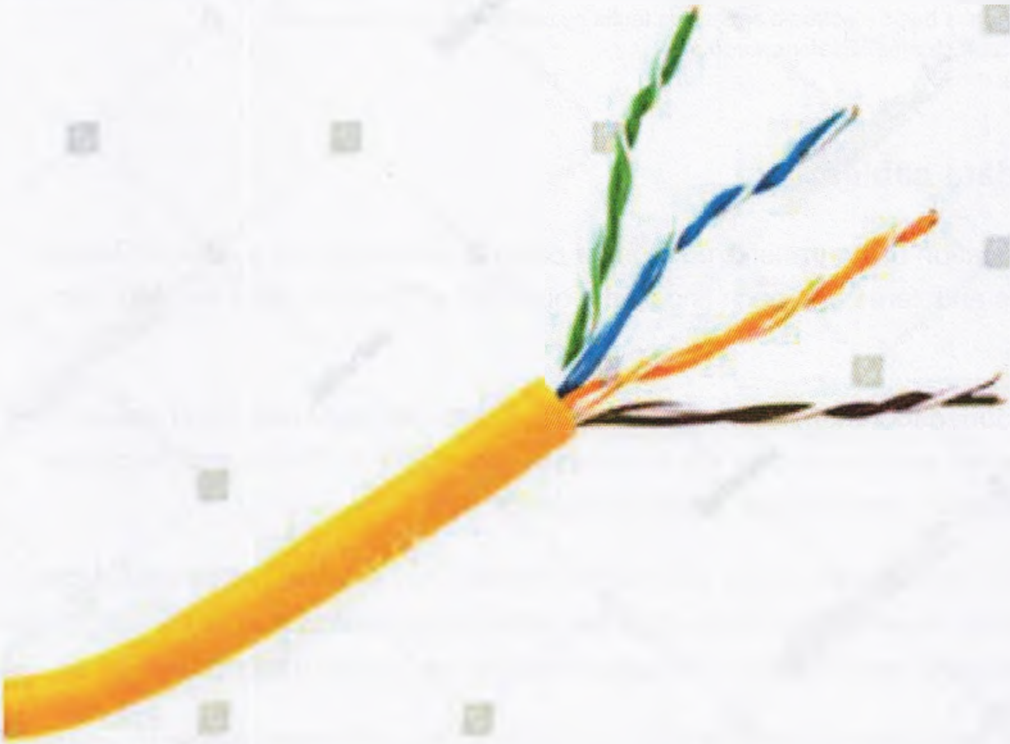
Data rate refers to the amount of data the cable is sending or receiving per second (Mbps); for example, a data rate of 1 MHz shows that the cable is transferring one million bits of data per second. The cable may be able to transfer more, but the current data rate is 1 Mbps.

Although related, bandwidth is different from data rate. Bandwidth refers to how much the cable is capable of receiving or transmitting. It isn't a measure of what is actually being transferred, which is the data rate.

Twisted-pair cables

Ethernet cables have four pairs of conductors; that is, eight wires in groups of two. Each pair is twisted together and forms a circuit. The pairs are then all twisted together within the cable. The twisting is important to assist in minimising interference from electromagnetic interference (EMI).

Four pairs of twisted cables



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Note that each pair is twisted differently, with some having greater twisting than others. This is to reduce interference between the conductors themselves. The idea is to stop any single conductor from being exposed to an interfering signal. As the twisted pairs lie next to each other within the cable, twisting each pair differently reduces the chance of one conductor from one pair interfering with another conductor of a different pair.

To further reduce the effects of interference, the grouped pairs can be shielded with a foil or a wire mesh. The shielding can be around the group of conductors or around the individual conductors or even both. Simple foil shielding around the conductors is called FTP (or F/UTP) for 'foil twisted pair', while unshielded twisted pairs are called UTP.

Solid conductors are mostly used, although for extra flexibility the conductors may be stranded.

Four-pair cable conductor colour coding

Wire number	Pair number	Colour
1	1	White/blue
2	1	Blue
3	2	White/orange
4	2	Orange
5	3	White/green
6	3	Green

Wire number	Pair number	Colour
7	4	White/brown
8	4	Brown

Originally, the UTP cables were developed to carry analogue voice signals, especially for telephone connection. These cables are now referred to as low-category (Cat) UTP cables. They fit into Cat 1 and Cat 2.

As the need for greater signal transfer grew, and data signals of a high frequency developed, so did the need for data grade cables. Data-grade cables fit into Cat 3 and above.

The data rate and bandwidth determine the category that the cable fits into.

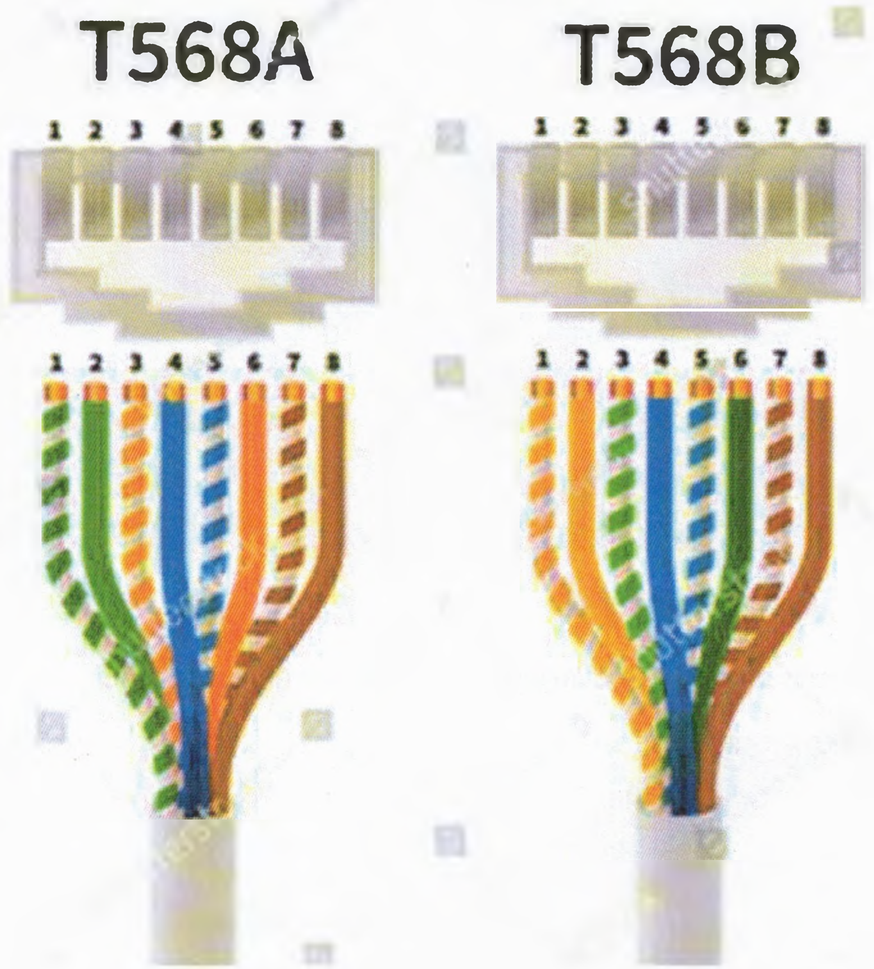
Category (Cat)	Maximum Data rate	Bandwidth	Maximum distance	Usage
Category 1	1 Mbps	0.4 MHz		Telephone and modem lines
Category 2	4 Mbps	4 MHz		Local talk and telephone
Category 3	10 Mbps	16 MHz	100 m	10BaseT ethernet
Category 4	16 Mbps	20 MHz	100 m	Token ring
Category 5	100 Mbps	100 MHz	100 m	100BaseT ethernet
Category 5e	1 Gbps	100 MHz	100 m	100BaseT ethernet, residential homes
Category 6	1 Gbps	250 MHz	100 m 10Gb at 37 m (121 ft)	Gigabit ethernet, commercial buildings
Category 6a	10 Gbps	500 MHz	100 m	Gigabit ethernet in data centres and commercial buildings

Category (Cat)	Maximum Data rate	Bandwidth	Maximum distance	Usage
Category 7	10 Gbps	600 MHz	100 m	10 Gbps core infrastructure
Category 7a	10 Gbps	1000 MHz	100 m	
40Gb at 50 m (164 ft)	10 Gbps core infrastructure			
Category 8	25 Gbps (Cat 8.1) 40 Gbps (Cat 8.2)	2000 MHz	30 m	25 Gbps/40 Gbps core infrastructure

Performance cable connectors

Standard modular connectors are used for these cables, which are terminated by crimping the conductors into the connector. The colour-coded wires fit into the connector in a standard pattern called a pin out; these are described in the standard ANSI/TIA-568. There are two connection pin-out alternatives: T586A and T586B. The preferred pair assignment for use in Australia is T568A.

T568A arrangement is preferred in Australia



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Terminating the connector using an 8P8C

The eight-position, eight-connection connector (8P8C, often called an RJ45 connector) is suitable for Cat 5, Cat 5e, Cat 6 and Cat 6A four-core twisted-pair cables.

Tools required:

- wire strippers
- wire cutters
- 8P8C (RJ45) crimping tool
- 8P8C (RJ45) modular data plug (the connector)
- network cable
- ruler.

8P8C modular connectors

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1. Cut the sheath back about 40 mm to expose the inner wires.

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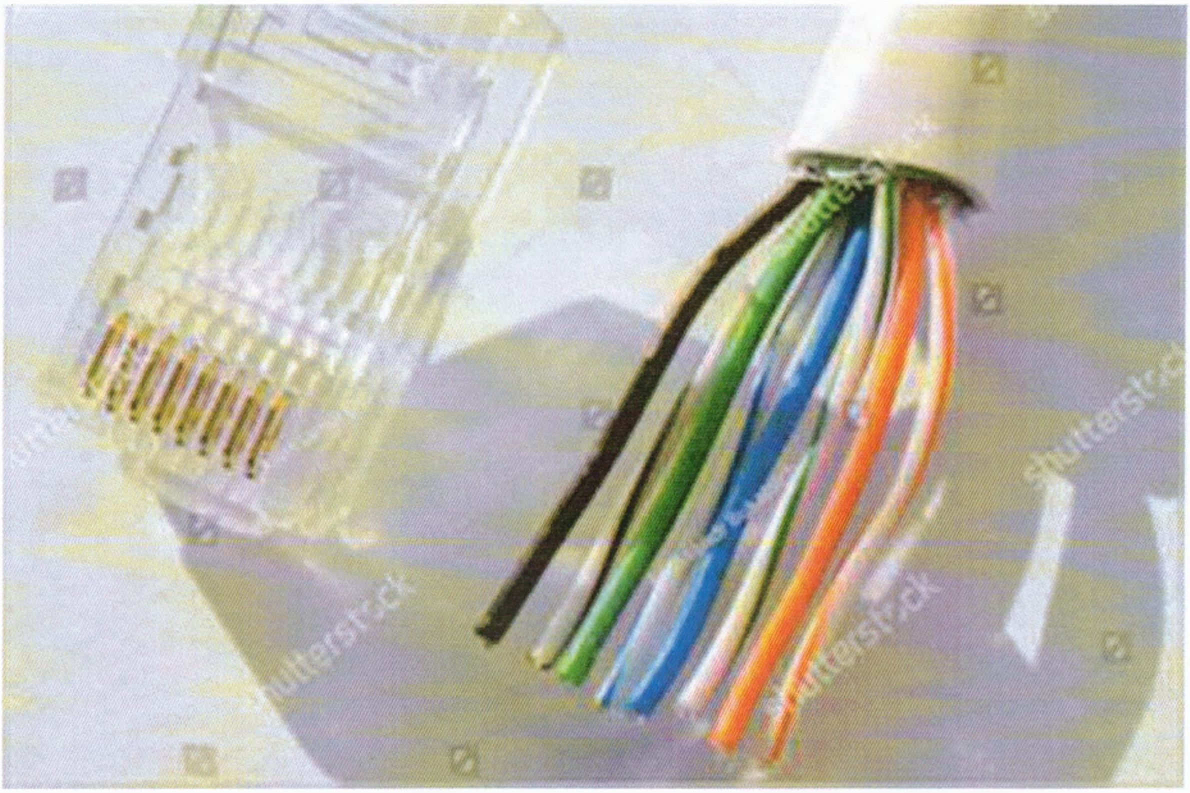
2. Trim the screen right back to the outer sheath and remove the plastic inner core.



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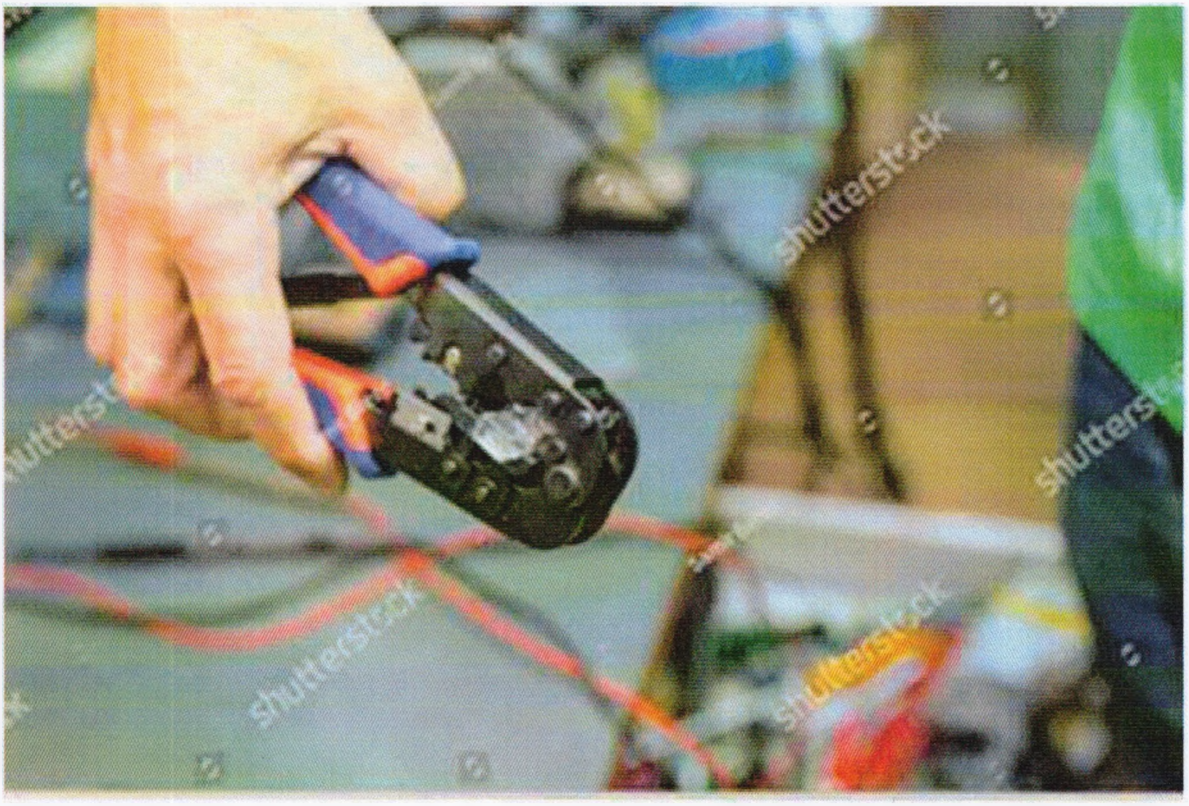
3. Untwist and straighten the conductors ready to fit onto the connector.
4. Arrange the conductors side by side in the order white/orange, solid orange, white/green, solid blue, white/blue, solid green, white/brown and solid brown.
5. Trim the conductors straight across about 15 mm from the edge of the cable sheath.
6. While holding the 8P8C (RJ45) connector plug with its contact pins pointing away from the conductors and its keyed tab (plug clip) facing downwards, gently push the wires right through the body of the plug.

Crimping the connector



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7. Using the crimping tool, press down firmly onto the connector around the cable. Small blades inside the connector pierce the insulation and flatten the individual wires, resulting in a secure mechanical and electrical contact. This method of piercing the insulation is called insulation displacement connector (IDC).

Once crimped, the cable is ready to be tested. A network cable tester will test a data cable that has 8P8C connectors on both ends. A multimeter on the ohms range can be used to test continuity and correct placement of the crimped wires.

Cable tester

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Rather than connect the conductors of a cable directly onto the pads of a PCB, it is good practice to fix a socket to the PCB and a matching plug to the cable. This has the advantage of reducing any strain on the soldered joint and allows the cable to be removed for repair or maintenance.

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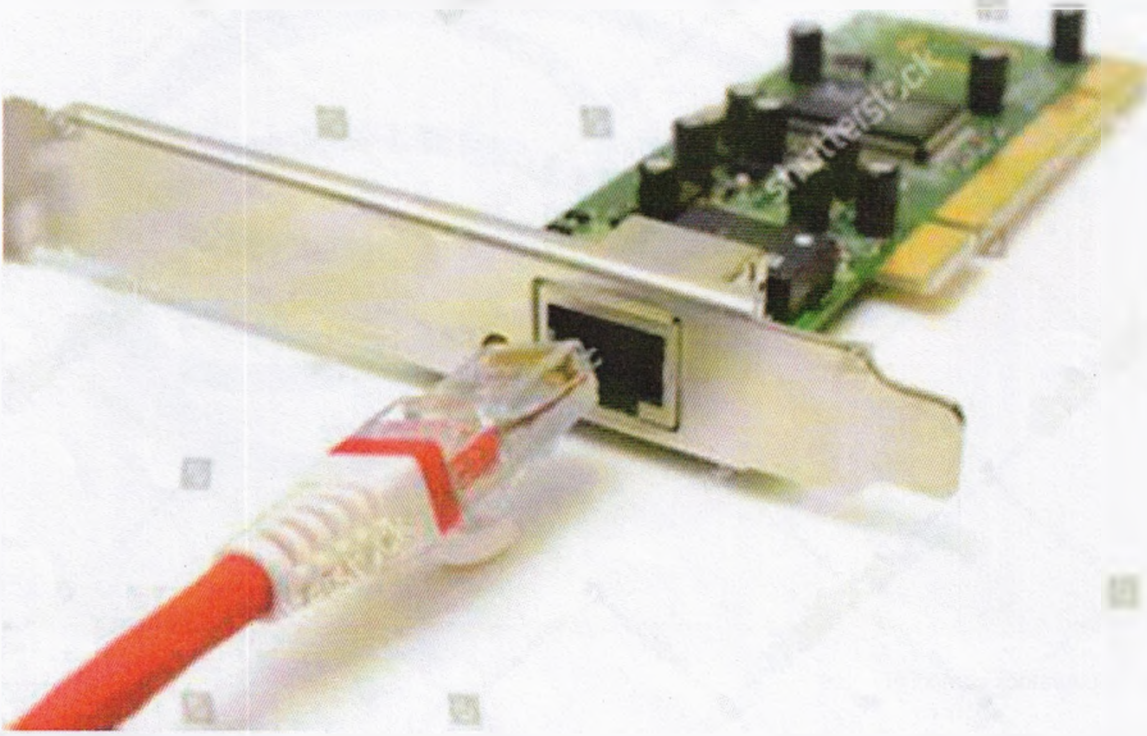
Where the conductors are to be soldered to the PCB pads, the cable must be securely clamped to avoid any strain from movement of the cable.

8P8C/RJ45 socket mounted to a PCB



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